

A MODERN FLATING ROOM.



# A COMPLETE TREATISE ON THE ELECTRO-DEPOSITION OF METALS.

COMPRISING

ELECTRO-PLATING AND GALVANOPLASTIC OPERATIONS, THE DEPOSITION OF METALS  
BY THE CONTACT AND IMMERSION PROCESSES, THE COLORING OF METALS,  
THE METHODS OF GRINDING AND POLISHING,

AS WELL AS

DESCRIPTIONS OF THE ELECTRIC ELEMENTS, DYNAMO-ELECTRIC  
MACHINES, THERMO-PILES, AND OF THE MATERIALS AND  
PROCESSES USED IN EVERY DEPARTMENT OF THE ART.

TRANSLATED FROM THE GERMAN OF

DR. GEORGE LANGBEIN,

PROPRIETOR OF A MANUFACTORY FOR CHEMICAL PRODUCTS, MACHINES, APPARATUS,  
AND UTENSILS FOR ELECTROPLATERS AND OF AN ELECTRO-PLATING  
ESTABLISHMENT, IN LEIPZIG.

WITH ADDITIONS BY

WILLIAM T. BRANNT,

EDITOR OF "THE TECHNO-CHEMICAL RECEIPT BOOK."

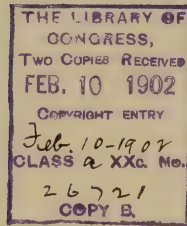
FOURTH EDITION, THOROUGHLY REVISED AND MUCH ENLARGED.

ILLUSTRATED BY ONE HUNDRED AND SIXTY ENGRAVINGS.

---

PHILADELPHIA:  
HENRY CAREY BAIRD & CO.,  
INDUSTRIAL PUBLISHERS, BOOKSELLERS, AND IMPORTERS.  
810 WALNUT STREET.  
1902.

TS670  
L3  
1902



---

COPYRIGHT BY  
HENRY CAREY BAIRD & CO.,  
1902.

---

25573

THE LIBRARY OF CONGRESS  
Two COPIES RECEIVED  
FEB. 10 1902  
COPYRIGHT ENTRY  
Feb. 10-1902  
CLASS a XXc. No.  
26721  
COPY B.

PRINTED AT THE  
WICKERSHAM PRINTING HOUSE  
53 and 55 North Queen Street,  
LANCASTER, PA., U. S. A.



## PREFACE TO THE FOURTH AMERICAN EDITION.

---

THE rapid sale of the third American edition of Dr. George Langbein's work, *Vollständiges Handbuch der Galvanischen Metall-Niederschläge*, and the continued demand for it, may be accepted as the best proofs of the value and usefulness of the book.

In the arrangement of the text in this, the fourth edition, now presented to the public, but few changes have been made. A number of new processes and improvements in older methods which have become known, and have been practically tested, since the publication of the previous editions, have been included, as well as the most recent machinery and apparatus, and special sections have been devoted to the quantitative determination of the contents of the baths most generally employed.

The editor is under obligations to the Hanson & Van Winkle Co., of Newark, N. J., the well-known manufacturers of, and dealers in, electro-platers' supplies, for valuable information and engravings.

The publishers have spared no expense in the proper illustration and the mechanical production of the work, and, like the previous editions, it has been provided with a copious table of contents and a very full index, so as to render reference to any subject prompt and easy.

W. T. B.

PHILADELPHIA, FEBRUARY 1, 1902.





## PREFACE TO THE FIRST AMERICAN EDITION.

THE art of the electro-deposition of metals has during recent years attained such a high degree of development that it was felt that a comprehensive and complete treatise was needed to represent the present advanced state of this important industry. In furtherance of this object, a translation of Dr. George Langbein's work, *Vollständiges Handbuch der Galvanischen Metall-Niederschläge*, is presented to the English-reading public with the full confidence that it will not only fill a useful place in technical literature, but will also prove a ready book of reference and a practical guide for the workshop. In fact, it is especially intended for the practical workman, wherein he can find advice and information regarding the treatment of the objects while in the bath, as well as before and after electro-plating. The author, Dr. George Langbein, is himself a master of the art, being the proprietor of an extensive electro-plating establishment combined with a manufactory of chemical products, machinery and apparatus used in the industry.

The results yielded by the modern dynamo-electric machines, to which the great advance in the electro-plating art is largely due, are in every respect satisfactory, and the more so since the need of accurate, and at the same time handy, measuring instruments has also been supplied. With the assistance of such measuring instruments, the establishment of fixed rules regarding the current-conditions for a galvanic bath has become possible, so that good results are guaranteed from the start. While formerly the electro-plater had to determine the proper current-strength for the depositions in an empirical manner, by time-consuming experiments, to-day, by duly observing the deter-

mined conditions and provided with well-working measuring instruments, he can at once produce beautiful and suitable deposits of the various metals.

The data referring to these current-conditions, according to measurements by Dr. Langbein, are given as completely as possible, while for the various baths, only formulæ yielding entirely reliable results have been selected. To most of the baths a brief review of their mode of action and of their advantages for certain uses is added, thus enabling the operator to select the bath most suitable for his special purpose. To the few formulæ which have not been tested, a note to that effect is in each case appended, and they are only given with due reserve.

To render the work as useful as possible, the most suitable formulæ for plating by contact and immersion, as well as the best methods for coloring the metals, and the characteristic properties of the chemicals used in the industry, are given. However, the preparation of the chemicals has been omitted, since they can be procured at much less expense from chemical works than it would be possible for the electro-plater to make them in small quantities, even if he possessed the necessary apparatus and the required knowledge of chemistry and skill in experimenting.

It is hoped that the additions made here and there by the translator, as well as the chapter on "Apparatus and Instruments," and that of "Useful Tables," added by him, may contribute to the usefulness of the treatise.

Finally, it remains only to be stated that the publishers have spared no expense in the proper illustration and the mechanical production of the book; and, as is their universal practice, have caused it to be provided with a copious table of contents, and a very full index, which will add additional value by rendering any subject in it easy and prompt of reference.

W. T. B.

PHILADELPHIA, JULY 1, 1891.

# CONTENTS.

## I.

### HISTORICAL PART.

#### CHAPTER I.

##### HISTORICAL REVIEW OF ELECTRO-METALLURGY.

	PAGE
The method of coating metals by simple immersion known to Zozimus and Paracelsus; Luigi Galvani's discovery, in 1789, of the electric contact-current; Alexander Volta's discovery, in 1799, of the true causes of the electric-contact current; Galvani's experiments . . .	1
Erroneous inference drawn by Galvani from his experiments; General ignorance in regard to the electric current; Discovery which led to the construction of the pile of Volta, or the voltaic pile; Cruikshank's trough battery . . . . .	2
Decomposition of water by electrolysis by Nicholson and Carlisle, 1800; Wollaston's observations, 1801; Cruikshank's investigations, 1803; Brugnatelli's experiments in electro-gilding, 1805; Sir Humphrey Davy's discovery of the metals potassium and sodium, 1807; Prof. Oersted's discovery of the deflection of the magnetic needle, 1820 . .	3
Construction of the galvanoscope or galvanometer; Ohm's discovery, in 1827, of the law named after him; Faraday's discovery in 1831, of electric induction; First electro-magnetic induction machine constructed by Pixii; Faraday's electrolytic law laid down and proved in 1833; Production of iridescent colors, in 1826, by Nobili; Production of the amalgams of potassium and sodium, in 1853, by Bird . .	4
Discovery of the actual galvanoplastic process, in 1838, by Prof. Jacoby; Claims of priority of invention by Mr. T. Spencer, and by C. J. Jordan; Labors of the Elkingtons, and of De Ruolz; Murray's discovery, in 1840, of black-leading; Introduction, in 1843, of gutta-percha by Dr. Montgomery; First employment, in 1840, of alkaline cyanides by Wright . . . . .	5
Patent for the deposition of nickel, 1840; Origination of the term "electro-metallurgy" by Mr. Alfred Smee, 1841; Prof. Boettger's	



	PAGE
discovery, in 1842, of the deposition of nickel from its double salt; First deposition of metallic alloys by De Ruolz; First use of thermo-electricity, in 1843, by Moses Poole; Advances in the art of electro-deposition . . . . .	6
The first magnetic machine that deposited silver on a practical scale constructed, in 1844, by Woolrych; Attempts, since 1854, by Christoffe & Co. to replace their batteries by magneto-electrical machines; The Alliance machine . . . . .	7
Objections to Wilde's machine; Dr. Antonio Pacinotti's invention, in 1860, of the ring named after him; Siemens' dynamo machine, 1866; Wheatstone's dynamo machine, 1867; Introduction, in 1871, of Zenobe Gramme's machine; Siemens & Halske's machine, 1884; S. Schuckert's machine, 1884 . . . . .	8
Various European and American constructions of dynamo-electrical machines; Investigators and practitioners who have contributed to the improvement of the electro-chemical processes and the perfection of galvano-plasty . . . . .	9

## II.

### THEORETICAL PART.

#### CHAPTER II.

##### MAGNETISM AND ELECTRICITY.

###### I. MAGNETISM.

Loadstone or magnetic iron ore; Natural and artificial magnets; Definitions of the magnetic poles and of the neutral line or neutral zone . . . . .	10
Magnetic meridian; North and south poles; Phenomena of attraction and repulsion; Ampère's theory . . . . .	11
The solenoid; Rejection of Ampère's theory by many scientific men; Definition of the magnetic field . . . . .	12

###### 2. ELECTRICITY.

Definition of idio-electrics and non-electrics; Gray's discovery; Good and bad conductors; The electroscope; Existence of two kinds of electricity, Vitreous, or positive, and resinous, or negative electricity. . . . .	13
Double fluid hypothesis of electricity; Single fluid hypothesis of electricity . . . . .	14

	PAGE
Investigations of Prof. Herz; Coulomb's law; Series of electro-motive force or tension . . . . .	15
The galvanic current or hydro-electric current; Galvanic element or galvanic chain; Electrical potential; Electro-motive force; Resistance.	16
Conducting power of metals; Quantity of current—Ohm's law . . .	17
Essential or internal resistance; Non-essential or external resistance .	18
Coupling of elements in various ways . . . . .	19
Coupling of elements for electro-motive force or tension; Coupling for quantity of current; Mixed coupling; Proposition deduced from Ohm's law . . . . .	20
Effects of the electric current . . . . .	21

### *Electro-magnetism.*

Rule for determining the direction which the magnetic needle will assume when placed in any particular position to the conducting wire.	21
Galvanoscope, galvanometers or multipliers; The astatic galvanometer; The tangent galvanometer; The sine galvanometer . . . . .	22
Electro-magnets; The solenoid; Law of the action of two electrified wires on each other . . . . .	23

### *Induction.*

Definition of induction . . . . .	23
Primary or inductive current; Secondary, induced or induction-current.	24
Alternating currents; Extra currents . . . . .	25

### *Chemical Action of the Electrical Current—Electrolysis.*

Reduction of the constituents of a fluid by the electric current; Pure water a bad conductor . . . . .	25
Faraday's discovery of the chemical actions of the electric current; Electrolysis; Electrolyte; Electrodes; Anode; Cathode; Ions; Anions; Kations; Atoms; Clausius' theory of the composition of matter . . .	26
Counter or polarizing current; Svante Arrhenius' theory of electrolytic dissociation; Electrolytes; Classification of the ions . . . . .	27
Table of most important ions; Formation of ions . . . . .	28
Hittorff's experiments; Osmotic pressure . . . . .	29
Explanation of the formation of the polarizing current; Faraday's electrolytic laws . . . . .	30
Local action; Electro-chemical equivalents; Joule's law . . . . .	32
Consumption of power in electrolysis; Electric units adopted by the International Congress of 1881; Fundamental or C. G. S. (centimetre-gramme-second) units; Force or power—dyne; Work—erg; Quantity; Potential or electro-motive force . . . . .	33
Resistance; The ohm; The ampère; The volt; The farad; The coulomb; The watt; Definition of English and of French horse-power . . .	34

### III.

## SOURCES OF CURRENT.

### CHAPTER III.

#### GALVANIC ELEMENTS—THERMOPILES—MAGNETO- AND DYNAMO-ELECTRIC MACHINES.

##### A. GALVANIC ELEMENTS.

	PAGE
The voltaic pile; Trough battery . . . . .	35
Reduction of local action by amalgamating the zinc; Various ways of amalgamation . . . . .	36
Bouant's recommendation; Definition and cause of polarization; Smee's element . . . . .	37
Constant elements; Daniell's element . . . . .	38
Meidinger element . . . . .	39
Grove element; Bunsen elements . . . . .	40
Improved Bunsen cell . . . . .	42
Electroplating and its composition; Best location of elements . . . .	43
Dupré's substitute for sulphuric and nitric acids for filling elements; A soluble chromium combination which depolarizes with rapidity . . .	44
Inspection and cleansing of the binding screws; Manipulation of Bunsen elements . . . . .	45
Advisability of having a duplicate set of porous clay cells; Renewal of the acid; Foote's pinnacle gravity battery . . . . .	46
Oppermann's element . . . . .	47
Leclanché element; Lalande and Chaperon element . . . . .	51
The cupron element . . . . .	53
Various elements; Dun's potash element . . . . .	54
Element patented by Knafke and Kiefer, of Vienna . . . . .	55
Plunge or bichromate batteries; The Bunsen plunge battery; Fein's bichromate battery . . . . .	56
Keiser and Schmidt's bichromate battery . . . . .	57
Bichromate element for gilding or silvering small articles . . . .	58
Stoehrer's element; Plunge element manufactured by Dr. G. Langbein & Co. . . . .	59

##### B. THERMO-ELECTRIC PILES.

Prof. Seebeck's discovery, in 1822, of a new source of electricity . . .	60
--	----



	PAGE
Definition of a thermo-electric couple and of thermo-electricity; Noe's thermo electric pile; Clamond's thermo-electric pile . . . . .	61
Hauck's thermo-electric pile . . . . .	62
Gülcher's thermo electric pile . . . . .	63

## C. MAGNETO- AND DYNAMO-ELECTRIC MACHINES.

Faraday's discovery, in 1831 . . . . .	65
Magnetic field or the region of the lines of force; What a magneto-electric or dynamo-electric machine actually is . . . . .	66
Prof. S. P. Thompson's definition of a dynamo-electric machine . . . . .	67
Pixii's electrical machine, 1832; Saxton and Clarke's improvements; Dr. W. Siemens' improvement, 1857; Pacinotti's ring armature, 1860; Dr. W. Siemens' and Sir C. Wheatstone's simultaneous discovery . . . . .	68
Classes of electric generators; Continuous current and alternating current machines; The Gramme machine . . . . .	69
The Gramme armature; Modern Gramme dynamo for galvanoplastic purposes . . . . .	70
Disadvantage of the Gramme machine . . . . .	71
S. Schuckert's flat ring machine . . . . .	72
Substitution of a dynamo of the drum-armature type for the flat ring machine; Fein's dynamo machine . . . . .	73
Siemens & Halske's dynamo-electric machines . . . . .	74
Kroettlinger dynamo . . . . .	76
Lahmeyer dynamo . . . . .	77
Shunt-wound dynamo constructed by Dr. G. Langbein & Co.; Armature of this dynamo . . . . .	79
Resume of the evolution of the dynamo for plating purposes in the United States . . . . .	80
The Weston dynamo; "Little Wonder" dynamo; The "Wonder" dynamo . . . . .	81
The new Hanson & Van Winkle dynamo . . . . .	82
Direct connected motors to machines; Mode of connecting the generator and motor . . . . .	85
Various dynamo machines; Value of the dynamo, and its effect upon the electro-plating industry . . . . .	86
Data for the most suitable machine . . . . .	87

## D. SECONDARY ELEMENTS (ACCUMULATORS).

Planté's practical application of accumulators, and his accumulator . . . . .	87
Faure's use of lead grids . . . . .	88
Storage capacity of accumulators; Chemical processes which take place in the accumulator; Elbs's theory . . . . .	89
Liebenow and Loeb's theory . . . . .	90
Common form of an accumulator; Charging the accumulator; Diagram showing the connection of a plant as installed by the Electro-Chemical Storage Co. of New York . . . . .	91

## IV. PRACTICAL PART.

### CHAPTER IV.

#### ARRANGEMENT OF ELECTRO-PLATING ESTABLISHMENTS IN GENERAL.

	PAGE
Necessity of sufficient light and thorough ventilation . . . . .	93
Location of Bunsen elements; Provision for heating . . . . .	94
Importance of a good supply of water; Best materials for floors . . . . .	95
Size of the operating room; Grinding and polishing rooms . . . . .	96
Prevention of dust in the polishing room; Location of the transmission carrying the belt pulleys . . . . .	97

#### ELECTRO-PLATING ARRANGEMENTS IN PARTICULAR.

Parts constituting the actual electro-plating plant; Arrangement with elements . . . . .	97
Choice of coupling the elements; Proportion of the effective zinc surface of the elements to that of the anodes and articles . . . . .	98
Requisites as regards the result of the process of deposition . . . . .	99
Coupling of elements for thick, solid, and thin deposits . . . . .	100
Auxiliary apparatus; The rheostat, current-regulator, resistance-board or switch board . . . . .	101
Conditions upon which the action of the resistance-board is based . . . . .	102
Horizontal and vertical galvanometers . . . . .	103
Location of the resistance-board and galvanometer; Improved H. and V. W. patent underwriter's switch-board . . . . .	104
Indications made by the galvanometer . . . . .	106
Positive or anode wire; Negative or object wire; Vats or tanks; Wooden vats and their construction . . . . .	109
Wooden vats lined with sheet lead for acid copper and nickel baths . . . . .	110
Objections to such vats; Enameled iron vats; Agate vessel for gold and other solutions . . . . .	111
Conducting rods; Anodes and their arrangement . . . . .	112
Binding posts and screws; Mode of suspending the anodes . . . . .	113
Mode of suspending the objects; Slinging wires; Protection of the conducting rods; Cleansing and rinsing apparatus . . . . .	114
Dipping or pickling; Sawdust for drying the objects; Arrangement with dynamo-electric machines; Rules for setting up and running a dynamo . . . . .	115
Insulation of the object- and anode- wires; Special wire carriers; Arrangement with one machine which has to feed several baths . . . . .	117

Scheme of a dynamo, with the auxiliary apparatus, the main conducting wire and a few baths; Location of the dynamo rheostat: The ampèremeter or ammeter, and the voltmeter; On what the character of a deposit obtained in a certain solution largely depends . . . . .	118
The Starrett improved voltmeter . . . . .	120
The little H. & V. W. voltmeter; The Weston voltmeter . . . . .	121
The Weston ammeter . . . . .	122
Scheme showing the coupling of the main object wire and the main anode wire with the resistance-boards, the voltmeter, the switch, and two baths . . . . .	123
Ground-plan of an electro-plating establishment . . . . .	125
Table for freeing the articles from grease . . . . .	127
Plating-room arranged by the Hansen & Van Winkle Co., of Newark, N. J.; Mode of calculating the thickness of the conducting wires for dynamos . . . . .	129

## CHAPTER V.

## TREATMENT OF METALLIC ARTICLES.

## A. MECHANICAL TREATMENT.

Treatment before electro-plating; Scratch-brushing; Formation of the deposit in correspondence with the surface of the basis-metal . . . . .	132
Modes of scratch-brushing; Various forms of brushes . . . . .	133
Treatment of scratch-brushes; Circular scratch-brushes . . . . .	134
Circular scratch-brush for cleaning purposes, and its construction . . . . .	135
Brushes; Use of sand blast for cleaning . . . . .	136
The La Pierre patent sand blast; Other types of sand blasts . . . . .	137
Sand blast combined with a scouring drum . . . . .	138
Cleaning metallic surfaces in the tumbling barrel or drum . . . . .	139
Adjustable oblique tumbling barrel . . . . .	141
Grinding; Grinding wheels and their construction . . . . .	142
Grinding wheels of pasteboard and of cork waste . . . . .	143
Roughing wheel, medium wheel, and fine wheel; Treatment of the grinding wheels . . . . .	144
Vienna lime; Grinding lathes . . . . .	145
Execution of grinding; Fibres . . . . .	146
Fibre brushes; Grinding iron and steel articles . . . . .	147
Grinding brass and copper castings, sheets of brass, German silver and copper, zinc castings, sheet zinc; Polishing . . . . .	148
Foot-lathe for polishing; Cloth bobs; Union canvas wheel; Walrine wheel . . . . .	149
Foot-power grinding and polishing lathe; Double polishing lathes; Lathe manufactured by the Hanson & Van Winkle Co. . . . .	150
Electrically driven grinding and polishing lathes . . . . .	152

	[PAGE
Glue pot; Belt strapping attachment or endless belt machine . . . . .	153
Flexible shafts for grinding, polishing and buffing . . . . .	154
Polishing materials; Rouge composition . . . . .	155
Burnishing; Mechanical treatment during and after the electro-plating process; Scratch-brushing the deposits . . . . .	156
Effect of scratch-brushing; Scratch-brushes used for different metals; Decoctions used in scratch-brushing . . . . .	157
Scratch-brushing by hand . . . . .	158
Lathe-brush; Treatment of the finished electro-plated objects; Sawdust for drying the objects; Method of freeing nickeled objects from moisture . . . . .	159
Polishing deposits of nickel, copper, brass, tin, gold and silver and platinum; Operation of burnishing and forms of burnishers . . . . .	160

## B. CHEMICAL TREATMENT.

Pickling and dipping; Mixture for pickling cast-iron and wrought-iron objects; Excellent pickle for iron; Pickling in the electrolytic way; Duration of pickling . . . . .	162
Pickling zinc objects; Cleansing and brightening copper and its alloys, brass, bronze, tombac and German silver; Preliminary pickle; Bright-dipping bath . . . . .	163
Use of potassium cyanide for pickling; Handling of pickled objects; Matting . . . . .	164
Matting by chemical means; Mixture for the production of a matt-grained surface by pickling; Matting by mechanical means . . . . .	165
Matting by galvanoplasty; Main points in pickling . . . . .	166
Absorbing plant for escaping acid vapors . . . . .	167
Regaining of acid and metal from exhausted dipping baths . . . . .	168
Removal of grease and cleansing . . . . .	169
Preparation of lime mixture; Cleansing with benzine . . . . .	170
Tying the objects to metallic wires; Removal of oxide from the metallic objects . . . . .	171
Steel spring carboy rocker . . . . .	172

## CHAPTER VI.

## PROCESSES OF ELECTRO-DEPOSITION.

Importance of the constitution of the water used as a solvent; Spring and well water; Rain water . . . . .	173
Importance of the purity of the chemicals used; Examples of difference in chemicals . . . . .	174
Concentration of the baths; Non-reliability of measurement by hydrometer degrees . . . . .	175
Effects of baths too poor in metal, and too concentrated; Stirring up the baths . . . . .	176



# CONTENTS.

XV

	PAGE
Effect of heavier and more saturated fluid on the anodes; Constant agitation of the baths by mechanical means; Advantage of constant agitation in silvering and in galvano-plastic operations . . . . .	177
Bossard mechano-electroplating tanks . . . . .	178
Electro-plating apparatus for mechanical electro-plating, patented by the Electrolytic Plating Apparatus Co., of Walsall and Birmingham, England; Temperature of the baths . . . . .	180
Boiling of the baths; Kettles and boiling pans; Solution of nickel salts dissolving with difficulty . . . . .	181
Filtration of the boiled solutions; Means of securing lasting qualities to the bath; Choice of anodes . . . . .	182
Alloying of the deposit with the basis-metal; Gore's experiments . . . . .	183
Conditions for the good performance of an electrolytic bath; Reduction of metals without a battery (electro-deposition by contact) . . . . .	184
Reduction of metal by dipping one metal into one fluid . . . . .	185

## CHAPTER VII.

### DEPOSITION OF NICKEL AND COBALT.

#### I. NICKELING.

Growth and popularity of nickel-plating; Properties of nickel . . . . .	186
Nickel baths; General rules for preparing nickel baths; The active constituent in many prepared nickeling salts . . . . .	187
Use of the chlorine combinations; Additions to the nickel bath recommended by various experts; Effects of the presence of small quantities of free acid; Boric acid as an addition to nickeling and all other baths . . . . .	188
Action of boric acid; Determination of the acidity, alkalinity and neutrality of nickel baths . . . . .	189
Formulæ, preparation, characteristics and treatment of nickel baths . . . . .	190
Burning or over nickeling . . . . .	191
Nickel baths containing boric acid; Weston's bath . . . . .	192
Kaselowsky's formula; Preparation of a nickel bath containing boric acid . . . . .	193
Nickel baths for special purposes . . . . .	194
Bath for nickeling of a dark tone . . . . .	195
Compositions of a few nickel baths which have been highly recommended; An English formula; Addition of bisulphide of carbon to nickel baths; Bath for nickeling small articles; Bath for the production of very thick deposits . . . . .	196
Correct working of freshly-prepared nickel baths; Cause of the deposition of somewhat more brittle nickel by freshly-prepared baths; Peeling off of the deposit . . . . .	197
Nickel bath without nickel salt; Nickel anodes . . . . .	198

	PAGE
Objections to insoluble anodes . . . . .	199
Use of rolled and cast anodes together in one bath . . . . .	200
Size of anode-surface; Cause of a reddish tinge on the anodes; Manner of suspending the anodes; Restoration of the neutrality, or of a slightly acid reaction of a nickel bath; Process of nickeling . . . . .	202
Coppering or brassing articles previous to nickeling . . . . .	203
Suspension of the objects in the bath . . . . .	204
Suitable current-strength for nickeling; Burning or over-nickeling . . . . .	205
Criteria for judging whether the nickeling progresses with a correct current-strength; Density of current most suitable for nickeling . . . . .	206
Solid nickeling . . . . .	207
Test for sufficiently heavy nickeling; Arrangement of object-rods and anode-rods; Most suitable distance of the anodes from the object . . . . .	208
Use of the hand-anode; Additional rules for nickeling and other electro-plating processes; Rules for suspending the objects in the bath . . . . .	209
Polarizing phenomena . . . . .	210
Nickeling <i>en masse</i> of small and cheap objects . . . . .	211
Warren's solutions of nickel and of cobalt to be decomposed in a simple cell apparatus; Contrivances for electro-plating small articles <i>en masse</i> . . . . .	213
Dr. Geo. Langbein & Co.'s apparatus for this purpose; Plating drum recommended by Pfanhauser . . . . .	214
Rocking apparatus patented by Dr. Geo. Langbein & Co. for plating rods, bicycle spokes, chains, etc.; Arrangement for suspending bicycle spokes in the bath . . . . .	216
Stripping nickeled articles; Stripping acid . . . . .	217
Stripping by brushing; Stripping by means of the battery or the dynamo; Remedy against a yellowish tone of nickeling; Resumé of the principal phenomena which may occur in nickeling, and their avoidance . . . . .	218
Refreshing nickel baths . . . . .	220
Treatment of articles after nickeling; Polishing nickel deposits; Treatment of articles which are to remain matt; Nickeling sheet zinc . . . . .	221
Preliminary grinding and polishing; Construction of cloth bobs . . . . .	222
Mode of polishing or grinding the sheets . . . . .	223
Self-acting sheet polishing machines; F. Räuber's sheet-grinding and polishing machine . . . . .	224
Automatic sheet-polishing machine constructed by F. W. Koffler, of Vienna . . . . .	228
Automatic sheet-polishing machine constructed by Friedr. Krupp, Grusonwerk, Magdeburg-Buckau, Germany . . . . .	230
Cleansing zinc sheets; Nickeling the sheets . . . . .	232
Advantages of previous coppering or brassing; Prevention of the peeling-off of the nickel deposit . . . . .	233
Coppering the sheets; Dimensions of vats for nickeling the sheets . . . . .	234

	PAGE
Anodes used for nickeling sheet-zinc, and proportion of anode-surface to zinc-surface; Cause of black streaks and stains . . . . .	235
Augmentation of the metallic content of the bath; Polishing the nickeled sheets; Nickeling tin-plate, Nickeling copper and brass sheets . . . .	236
Nickeling sheet-iron and sheet-steel . . . . .	237
Nickeling wire and apparatus for that purpose . . . . .	238
Nickeling wire-gauze; Nickeling knife-blades, sharp surgical instruments, etc. . . . .	240
Nickeling skates . . . . .	241
Nickeling printing plates (electrotypes, clichés, etc.); Hard nickeling and baths for that purpose . . . . .	242
Recovery of nickel from old baths; Urquhart's plan for recovering nickel from old solutions; To improve defective nickeling . . . . .	244
Arrangement of the "doctor;" Nickeling by contact and boiling . . . .	245
Deposition of an alloy containing nickel according to R. Kaiser; Deposits of nickel alloys; Nickel-bronze . . . . .	247
French process for the deposition of German silver; Watt's method . . .	248
Examination of nickel baths; Method for the determination of the content of acid . . . . .	249
Methods for the examination of baths; Gravimetric analysis . . . . .	251
Volumetric analysis . . . . .	252
Electrolytic method of analysis . . . . .	253
Apparatus for electrolytic analysis; Washing contrivance . . . . .	254
Examination of a nickel bath by electrolytic analysis . . . . .	256

## 2. DEPOSITION OF COBALT.

Properties of cobalt; Baths for plating with cobalt . . . . .	256
Cobalting of copper plates for printing; Determination of the quantity of copper dissolved in stripping the cobalt deposit from cobalted copper plates . . . . .	257
Warren's cobalt solution; Cobalt solution recommended by G. W. Beardslee, of Brooklyn, N. Y.; Daub's bath for cobalting small fancy articles . . . . .	258
Cobalting by contact . . . . .	259

## CHAPTER VIII.

## DEPOSITION OF COPPER, BRASS AND BRONZE.

## 2. DEPOSITION OF COPPER.

Properties of copper; Copper baths, their composition, preparation, properties, and treatment . . . . .	261
Hassauer's copper bath; Copper baths for iron and steel articles . . . .	262
Baths for coppering zinc articles . . . . .	263
Baths prepared with cupron and copper sulphite . . . . .	265
Copper baths without potassium cyanide; Weil's copper bath and method of coppering; Copper bath recommended by Walenn . . . . .	266



	PAGE
Copper bath according to Pfanhauser; Gauduin's copper bath; Execution of copper-plating . . . . .	267
Anodes used; Formation of slime on the anodes; Phenomena in baths containing cyanide . . . . .	268
Necessity of carefully cleaning and pickling the articles before coppering; Scratch-brushing and treatment of defective places . . . . .	269
Prevention of the formation of stains; Schultz's patent to prevent the formation of stains; Polishing the deposit of copper . . . . .	270
Treatment of coppered articles to be coated with another metal; Coppering sheet iron or sheet zinc which is to be nickeled . . . . .	271
Coppering small articles <i>en masse</i> ; Coppering by contact and dipping; To coat zinc plates with a very thin but hard layer of copper . . . . .	272
Bacco's copper bath; Brush coppering; Application of a thin film of copper to iron and steel objects; Coppering steel pens, needles' eyes, etc. . . . .	273
Inlaying of depressions of coppered art-castings; Examination of copper-baths containing potassium cyanide . . . . .	274
Determination of potassium cyanide . . . . .	275
Determination of copper by electrolysis . . . . .	277
Volumetric determination of copper . . . . .	278

## 2. DEPOSITION OF BRASS (*Cuivre-poli* Deposition).

Constitution and varieties of brass . . . . .	280
Brass baths, their composition, preparation and treatment; Rules for baths containing more than one metal in solution; Brass bath according to Roseleur . . . . .	281
Irregular working of fresh baths; Effect of an addition of arsenious acid to brass baths . . . . .	282
Bath for brassing iron; Baths with cuprous sulphide . . . . .	283
Bath for brassing zinc; Bath for brassing cast-iron, wrought-iron and steel . . . . .	284
Norris and Johnson's brass bath; Solution for transferring any copper-zinc alloy which serves as anode; Bath for brassing all kinds of metal. . . . .	285
Execution of brassing; On what the color of the deposit depends . . . . .	286
Anodes used and anode-surface required; Formation of slime on the anodes, and what it indicates; Remedies for the slow formation of the deposit . . . . .	287
Importance of the distance of the objects to be plated from the anodes; Brassing of unground iron castings; Brassing by contact and dipping. . . . .	289
Examination of brass baths; Determination of free potassium cyanide and the content of copper; Determination of zinc by electrolysis . . . . .	290
Volumetric determination of zinc . . . . .	291

## 3. DEPOSITION OF BRONZE.

Gountier's solution for coating wrought- and cast-iron with bronze; Other bronze baths, their composition, preparation and treatment . . . . .	292
--	-----

Hess's bath for deposits of tombac; Execution of bronzing . . .	293
---	-----

CHAPTER IX.

DEPOSITION OF SILVER.

Properties of silver; Statistics of the amount of silver used in electro-plating . . . . .	294
Silver baths, their composition, preparation and treatment; Silver bath for a heavy deposit of silver (plating by weight) . . . . .	295
Preparation of baths with silver chloride . . . . .	296
Preparation of baths with silver cyanide; Preparation of silver cyanide .	297
Silver bath for ordinary electro-silvering; Treatment of silver baths—Silver anodes . . . . .	298
Most suitable current-strength for silver baths; Coupling of the elements; Indication of the presence of too much, or not enough potassium cyanide . . . . .	299
The behavior and appearance of the anodes as criteria of the content of potassium cyanide in the bath; Keeping the bath constant by silver anodes . . . . .	300
Proper treatment of baths made with silver chloride; Gradual thickening of the baths . . . . .	301
Augmentation of the content of silver in baths; Determination of the content in proper proportions of silver and excess of potassium cyanide.	302
Contrivances to keep the objects to be plated in constant agitation .	303
Singular phenomenon in regard to silver baths; Preparations for "bright-plating" . . . . .	304
Remedy against a yellow tone of the silver-plating; Arcas silver-plating as introduced by the London Metallurgical Co. . . . .	306
Experiments in arcas silver-plating . . . . .	307
Execution of silver-plating; Silver-plating by weight; Mechanical and chemical preparation of the objects; Treatment of copper and its alloys . . . . .	308
Freeing from grease; Pickling; Rubbing; Pickling in the preliminary pickle; Amalgamating (quicking); Sliding wires . . . . .	309
Treatment of the objects while being being plated . . . . .	310
Amount of silver deposited upon various grades of plated table-ware manufactured by the William Rogers Manufacturing Co.; Method of controlling the weight of the deposit . . . . .	311
Roseleur's plating balance . . . . .	312
Plating balance together with the resistance-board, voltmeter, and silver bath . . . . .	314
Treatment of articles which are to retain the crystalline dead white, with which they come from the bath; Polishing the articles; Ordinary silver-plating . . . . .	315
Gore's process of silver-plating Britannia ware and articles of tin; Australian patent for directly silver-plating iron and steel . . . .	316

	PAGE
Practice of the Meriden Britannia Co.'s works at Meriden, Conn.; Treatment of Britannia or "white metal," German silver and nickel articles, and of steel articles . . . . .	317
Methods in use with the Wm. Rogers Manufacturing Co., Hartford, Conn.; For cleansing steel (cutlery); Nickel-silver (German silver) for spoons; Britannia metal (hollow ware); Rogers's striking solution; Meriden Company's striking solution; Plating solution commonly used by the Wm. Rogers Manufacturing Co. . . . .	318
Methods of depositing an extra heavy coating of silver on the convex surfaces of spoons and forks; Stopping-off and stopping-off varnish . . . . .	319
Silvering by contact, by immersion, and cold silvering with paste; Bath for silvering by contact; Baths for silvering by immersion . . . . .	320
Preparation of solution of sodium sulphide . . . . .	321
Dr. Ebermayer's silver-immersion bath; Silvering articles without the use of the current . . . . .	323
Coating small articles, such as hooks and eyes, pins, etc., with a thin film of silver; Cold silvering with paste . . . . .	325
Composition of argentiferous pastes; Graining . . . . .	326
Preparations used for graining . . . . .	327
Operation of graining; Resist and its composition; Gilding of grained watch parts . . . . .	328
Silvering of fine copper wire . . . . .	329
Imitation of niel or nielled silvering; Preparation of the nielling powder. . . . .	330
Imitation of niel by electro-deposition; Nielling upon brass; Old (antique) silvering . . . . .	331
Oxidized silver; Yellow color on silvered articles . . . . .	332
Stripping silvered articles; Determination of silver-plating . . . . .	333
Method for the determination of genuine silvering used by custom-house officers in Germany; Examination of silver baths; Determination of free potassium cyanide . . . . .	334
Determination of potassium carbonate . . . . .	335
Calculation of the quantity of barium cyanide required for the conversion of the potassium carbonate; Determination of silver by the electrolytic method . . . . .	336
Recovery of silver from old silver baths, etc.; The wet method . . . . .	337
Various methods of regaining the silver . . . . .	338

## CHAPTER X.

## DEPOSITION OF GOLD.

Occurrence of gold; General composition of the native metal; Properties of gold . . . . .	340
Shell gold or painter's gold; Gold baths, their composition, preparation and treatment . . . . .	341

	PAGE
Bath for cold gilding . . . . .	342
Bath with yellow prussiate of potash for cold gilding . . . . .	343
Baths for hot gilding . . . . .	344
Taucher's formulæ for hot gilding; Preparation of gold baths with the assistance of the current . . . . .	345
Management of gold baths; Use of insoluble platinum anodes and of steel anodes for gold baths . . . . .	346
Experiment with steel anodes . . . . .	347
Use of carbon anodes; Anodes of platinum for coloring the deposit; Coloration by means of the resistance-board . . . . .	348
Vats for gold baths; Porcelain dish for small baths . . . . .	349
Execution of gold-plating; Gilding without a battery . . . . .	350
Preparation of the articles for gilding; Current-strength for gilding . . . . .	351
Gilding the inner surfaces of hollow-ware; Process of gold-plating in the cold bath; Operations for plating with the hot bath . . . . .	352
Red gilding . . . . .	353
Determination of the content of copper required for obtaining a beautiful red gold; Green gilding; Rose-color gilding; Matt gilding . . . . .	354
Matting in the chemical or electro-chemical way . . . . .	355
Coloring of the gilding; Gilder's wax . . . . .	356
Process to give gilded articles a beautiful rich appearance; Method of improving bad tones of gilding . . . . .	357
Gilding metallic wire and gauze . . . . .	358
J. W. Spaeth's machine for gilding wire and gauze . . . . .	359
Gilding by contact, by immersion and by friction; Baths for contact gilding . . . . .	360
Porcelain capsules for dissolving gold . . . . .	361
Preparation of "matt" for gilded articles; Baths for gilding by dipping . . . . .	363
Gilding of porcelain, glass, etc. . . . .	365
Gilding by friction or gilding with the rag, with the thumb, with the cork; Martin and Peyraud's method of gilding by friction . . . . .	366
Fire or mercury gilding; Preparation of the gold amalgam; Application of the amalgam . . . . .	367
Method of gilding which is a combination of fire-gilding with electro-deposition . . . . .	369
Du Fresne's method of gilding . . . . .	370
Removing gold from gilded articles—Stripping; Determination of genuine gilding . . . . .	371
Examination of gold baths; Determination of the gold by the electrolytic method; Strengthening the gold bath . . . . .	372
Recovery of gold from gold baths, etc.; The wet process . . . . .	373
Recovery of gold from acid mixtures . . . . .	374



## CHAPTER XI.

## DEPOSITION OF PLATINUM AND PALLADIUM.

## I. DEPOSITION OF PLATINUM.

Properties of platinum; Platinum baths, their composition, preparation and properties . . . . .	375
Böttger's bath; Preparation of platoso-ammonium chloride; Platinum bath patented by the Bright Platinum Plating Co., of London; Dr. W. H. Wahl's directions for preparing platinum baths . . . . .	376
Alkaline platinate bath . . . . .	377
Preparation of an oxalate solution; Preparation of the phosphate bath.	378
Management of platinum baths . . . . .	379
Execution of platinum-plating; Production of heavy deposits; Platinizing glass . . . . .	380
Platinizing by contact; Recovery of platinum from platinum solutions.	381

## 2. DEPOSITION OF PALLADIUM.

Properties of palladium . . . . .	381
Bertrand's palladium bath; Pillet's bath for plating watch movements.	382

## CHAPTER XII.

## DEPOSITION OF TIN, ZINC, LEAD AND IRON.

## I. DEPOSITION OF TIN.

Properties of tin; Moiré metallique on tin; Tin baths, their composition, preparation and properties . . . . .	383
Direct tinning of objects of zinc, copper and brass; Preliminary coppering of iron and steel articles; Experiments with Salzède's bronze bath . . . . .	384
Pfanhauser's tin bath; Taucher's tin bath . . . . .	387
Management of tin baths; Current-strength required; Anodes; Choice of tin salts . . . . .	386
Process of tin-plating; Tinning by contact and boiling . . . . .	387
Zilken's solution for tinning by contact; Tinning solutions for iron and steel articles, and for small brass and copper articles; Böttger's solution . . . . .	388
Durable coating on tin; Tinning of needles . . . . .	389
Superficial coating of tin on articles of brass, copper and iron; Stolba's method of tinning . . . . .	390

## 2. DEPOSITION OF ZINC.

Properties of zinc . . . . .	390
Zinc baths, their composition, preparation and properties . . . . .	391
Anodes used in zincking . . . . .	392

	PAGE
Execution of zinc-plating; Zinc-plating of wrought-iron objects, girders, L-iron, T-iron, etc. . . . .	393
Profile anodes . . . . .	394
Zincking of nails, screws, etc.; Zincking iron by contact; To coat brass and copper with a bright layer of zinc . . . . .	395
Zinc alloys; Bath for depositing an alloy of zinc and tin, or of zinc, tin and nickel . . . . .	396

## 3. DEPOSITION OF LEAD.

Properties of lead . . . . .	396
Lead baths, their composition, preparation and properties; To coat gun barrels and other articles of steel and iron with superoxide of lead; Leading by contact; Metallic chromes (Nobili's rings, iridescent colors, electro-chromy) . . . . .	397
Gassiot's plan to obtain metallo-chromes . . . . .	399

## 4. DEPOSITION OF IRON (STEELING).

Principal use of the electro-deposition of iron . . . . .	399
Iron (steel) baths, their composition, preparation and properties; Varentrapp's iron bath; Böttger's steel bath . . . . .	400
Obernether's method of steeling copper printing plates; Production of a deep black deposit of iron for decorative purposes . . . . .	401
Management of iron baths . . . . .	402
Advantage of steeling of printing plates over nickeling; Steeling by contact . . . . .	403

## CHAPTER XIII.

## DEPOSITION OF ANTIMONY, ARSENIC, ALUMINIUM.

## I. DEPOSITION OF ANTIMONY.

Properties of antimony; Antimony baths, their composition, preparation and properties . . . . .	404
Schlippe's salt . . . . .	405

## 2. DEPOSITION OF ARSENIC.

Properties of arsenic . . . . .	405
Arsenic baths, their composition, preparation and properties . . . . .	406
Deposits of antimony and arsenic by contact and immersion . . . . .	407

## 3. DEPOSITION OF ALUMINIUM.

Properties of aluminium . . . . .	407
Aluminium baths; Bertrand's process; Goze's process; Reinbold's formula; New method for the electro-deposition of aluminium . . . . .	408
Electro-deposition upon aluminium . . . . .	409

	PAGE
Cleansing aluminium articles; Advisability of previous coppering and baths for that purpose; Villon's process . . . . .	410
Prof. Nees' process; Electro-deposits upon aluminium produced by the Mannesmann Pipe Works, Germany . . . . .	411

## CHAPTER XIV.

## GALVANOPLASTY (REPRODUCTION).

Definition of galvanoplasty; Copper the most suitable metal for galvanoplastic purposes; Physical properties of copper deposited by electrolysis; Smee's experiments; Hübl's experiments for the determination of the conditions under which deposits with different physical properties are obtained . . . . .	412
Classes of processes used in galvanoplasty . . . . .	413

## I. GALVANOPLASTIC DEPOSITION IN THE CELL-APPARATUS.

The cell-apparatus . . . . .	413
Simple cell-apparatus for amateurs; Cell-apparatus for the production of clichés . . . . .	414
Large apparatus; French form of cell-apparatus . . . . .	416
German form of cell-apparatus; Copper bath for the cell-apparatus; Table of the approximate content of pure crystallized blue vitriol at different degrees Bé, and 59° F. . . . .	417
Method of removing an excess of acid from the bath . . . . .	418

## 2. GALVANOPLASTIC DEPOSITION BY THE BATTERY AND DYNAMO.

Arrangement for the employment of external sources of current; Depositions with the battery; Coupling of elements . . . . .	419
Depositions with the dynamo; Copper baths for galvanoplastic depositions with a separate source of current . . . . .	420
Bath for depositing with the dynamo; Bath for depositing with the battery; Solution for copper printing plates . . . . .	421
Current-density for baths at rest and when agitated; Table showing the results of Hübl's experiments . . . . .	422
Disadvantage of difference in composition of the upper and lower layers of the bath; Various methods of effecting the agitation of the bath . . . . .	423
Anodes used for the baths . . . . .	424
Proportion of anode-surface to that of the cathodes; Examination of the acid copper bath; Determination of free acid; Volumetric determination of the content of copper according to Haën's method . . . . .	425
Electrolytic determination of the copper . . . . .	426
Preparation of moulds (matrices) in plastic material . . . . .	427
Moulding in gutta-percha; Most simple way of softening gutta-percha . . . . .	428
The toggle press . . . . .	429
Hydraulic press . . . . .	430

	PAGE
Moulding in wax (stearine); Volkmer's wax mixture; Preparation of the wax mould; Black-leading . . . . .	431
Black-leading machines . . . . .	432
Silas P. Knight's process of black-leading . . . . .	433
Preliminary coating of the black-leaded surface with copper; Gilt and silvered black-lead; Wiring the mould . . . . .	434
The building iron; The electric connection gripper; Suspension of the moulds in the bath . . . . .	435
Chief requisite for the production of a dense, coherent and elastic deposit; Strength of the sulphuric acid for filling the clay cells . . . . .	436
Most suitable current-density for the production of a good deposit; Coupling of the elements; Controlling the current by the resistance board . . . . .	437
Time required for a sufficiently heavy deposit; Accumulators and their use . . . . .	438
Detaching the deposit or shell from the mould; Casting and melting table . . . . .	439
Backing the deposit or shell . . . . .	440
Finishing; The saw table; Planing or shaving machine; Mounting the plates . . . . .	443
Process of making a copy directly from a metallic surface without the interposition of wax or gutta-percha . . . . .	444
Electro-etching . . . . .	445
Composition of etching ground . . . . .	446
Preparation of printing plates in relief; Heliography . . . . .	447
Electro-etching in steel for the production of dies for coins, reliefs, etc. . . . .	448
Galvanoplastic reproduction of busts, vases, etc. . . . .	449
Materials for the moulds; Dissection of the objects . . . . .	450
Oil gutta-percha, its preparation and use . . . . .	451
Metallic alloys for the preparation of moulds; Moulding with metallic alloys; Taking casts in plaster of Paris . . . . .	452
Moulding in plaster of Paris of large objects . . . . .	453
Mode of making plaster of Paris moulds impervious to fluids . . . . .	454
Metallization by the wet way . . . . .	455
Parkes's method of metallization . . . . .	456
Various methods of metallization; Metallization by metallic powders . . . . .	457
Lenoir's process—galvanoplastic method for originals in high relief; Gelatine moulds . . . . .	458
Brandle's directions for preparing gelatine moulds . . . . .	459
Special uses of galvanoplasty; Nature printing; Philipp's process for coating laces and tissues with copper; Production of copper tubes . . . . .	460
Corvin's niello; Coating grasses, leaves, flowers, etc. with copper . . . . .	461
Plates for the production of imitations of leather; To coat wood, etc., with a galvanoplastic deposit of copper; To protect wooden handles of surgical instruments, etc., from the attacks of the acid copper bath. . . . .	462



	PAGE
Copper deposit for the mercury vessels of thermometers; Metallization of glass, porcelain, clay, terra cotta, etc.; Galvanoplastic deposit of copper on porcelain, pottery, stone-ware, etc.; Galvanoplasty in iron (steel) . . . . .	463
Klein's bath; Lenz's investigations . . . . .	464
Prevention of the spoiling of the deposits . . . . .	465
Properties of electrolytically deposited iron; Advantages and disadvantages of iron electros and of steeled copper electros . . . . .	466
Galvanoplasty in silver and gold . . . . .	467
Baths for galvanoplasty in silver and in gold . . . . .	468

## CHAPTER XV.

## COLORING, PATINIZING, OXIDIZING, ETC., OF METALS — LACQUERING.

What is understood by patina and patinizing; Coloring of copper from the pale red of copper to a dark chestnut brown . . . . .	469
Brown color upon copper; Method used in the Paris Mint; Bronze-like color on copper . . . . .	470
Red-brown color on copper; Manduit's process of bronzing copper and coppered articles; Coloring copper blue black; <i>Cuivre fumé</i> ; Black color upon copper; Matt-black on copper . . . . .	471
Solution for obtaining a deep black color on copper and its alloys; Imitation of genuine patina . . . . .	472
Steel gray color upon copper; Coloring copper dark steel gray; Various colors upon massive copper and upon brass and nickel . . . . .	473
Coloring of brass and bronzes; Lustrous black on brass . . . . .	474
Steel gray on brass; Gray color with a bluish tint upon brass; Pale gold color on brass; Straw color, to brown, through golden yellow and tombac color on brass; A color resembling gold on brass . . . . .	475
Brown color, called bronze Barbédienne, on brass; Coloring bronze articles dead yellow or clay-yellow to dark brown . . . . .	476
Smoke-bronze; Dark red-brown color upon brass; Coloring brass articles <i>en masse</i> brown; Violet and corn-flower blue upon brass . . . . .	477
Spurious gilding of small silvered brass and tombac articles; Ebermayer's experiments in coloring brass . . . . .	478
Coloring zinc; Experiments in coloring zinc black . . . . .	479
Gray, yellow, brown to black colors upon zinc; Gray coating on zinc . . . . .	480
Bronzing on zinc; Brown patina on cast zinc; Red-brown shades on zinc; Yellow-brown shades on zinc; Coloring of iron; Browning of gun barrels . . . . .	481
Patina for protecting metals; Lustrous black on iron; Méritens process for obtaining a bright black color on iron . . . . .	482
Dead black coating on clock cases of iron and steel; Durable blue on iron and steel; Brown-black coating with bronze lustre on iron . . . . .	483
To give iron a silvery appearance with high lustre; Coloring of tin;	

Durable and very warm sepia-brown upon tin and its alloys; Dark coloration on tin; Lacquering; Use of lacquers in the electro-plating industry . . . . .	484
Application of lacquers; Operation of gold varnishers . . . . .	485
Varnishes at the disposal of gold varnishers; Resinous substances and tinctorial matters used in the manufacture of varnishes . . . . .	486
Removal of varnish from imperfectly varnished objects; Cellulose lacquers and varnishes; Zapon; Kristaline . . . . .	487
Preparation of a lacquer similar to zapon or kristaline; Lacquering articles by dipping . . . . .	488

## CHAPTER XVI.

## HYGIENIC RULES FOR THE WORKSHOP.

Neutralization of the action of acid upon the enamel of the teeth and the mucous membranes of the mouth and throat; Protection against the corrosive effect of lime and caustic lye . . . . .	488
Vessels used in the establishment not to be used for drinking purposes; Precautions in handling potassium cyanide and its solutions; Sensitiveness of many persons to nickel solutions; Poisoning by hydrocyanic (prussic) acid, potassium cyanide and cyanides; Remedies to be applied . . . . .	490
Poisoning by copper salts, by lead salts, by arsenic, by alkalies, by mercury salts and sulphuretted hydrogen . . . . .	491
Poisoning by chlorine, sulphurous acid, nitrous and hyponitric gases . . . . .	492

## CHAPTER XVII.

CHEMICAL PRODUCTS AND VARIOUS APPARATUS AND INSTRUMENTS  
USED IN ELECTRO-PLATING.

## A. CHEMICAL PRODUCTS.

I. *Acids.*

Sulphuric acid (oil of vitriol) . . . . .	493
Recognition of sulphuric acid; Nitric acid ( <i>aqua fortis</i> , spirit of nitre) and its recognition; Hydrochloric acid (muriatic acid) and its recognition; Hydrocyanic acid (prussic acid) . . . . .	494
Recognition of hydrocyanic acid; Citric acid and its recognition; Boric acid (boracic acid) and its recognition . . . . .	495
Arsenious acid (white arsenic, arsenic, ratsbane) and its recognition; Chromic acid and its recognition; Hydrofluoric acid . . . . .	496
Recognition of hydrofluoric acid . . . . .	497

*II. Alkalies and Alkaline Earths.*

Potassium hydrate (caustic potash); Sodium hydrate (caustic soda); Ammonium hydrate (ammonia or spirits of hartshorn) . . . . .	497
Calcium hydrate (burnt or quick lime) . . . . .	498

*III. Sulphur Combinations.*

Sulphuretted hydrogen (sulphydric acid, hydrosulphuric acid) and its recognition; Potassium sulphide (liver of sulphur) . . . . .	498
Recognition of potassium sulphide; Ammonium sulphide (sulphydrate or hydrosulphate of ammonia); Antimony sulphide; Black sulphide of antimony ( <i>stibium, sulfuraum nigrum</i> ); Red sulphide of anti- mony ( <i>stibium sulfuratum aurantiacum</i> ); Arsenic trisulphide or ar- senious sulphide (orpiment) . . . . .	499
Ferric sulphide . . . . .	500

*IV. Chlorine Combinations.*

Sodium chloride (common salt, rock salt) and its recognition; Ammo- nium chloride (sal ammoniac) and its recognition; Antimony trichlor- ide (butter of antimony) . . . . .	500
Arsenious chloride; Copper chloride; Tin chloride; Stannous chloride or tin-salt and its recognition; Stannic chloride; Zinc chloride (hy- drochlorate or muriate of zinc, butter of zinc) and its recognition .	501
Nickel chloride and its recognition; Cobalt chloride and its recogni- tion; Silver chloride . . . . .	502
Recognition of silver chloride; Gold chloride (terchloride of gold, mur- iate of gold, auric chloride) and its recognition; Platinic chloride and its recognition . . . . .	503

*V. Cyanides.*

Potassium cyanide (white prussiate of potash) . . . . .	504
Recognition of potassium cyanide; Comparative table of potassium cya- nide with a different content; Copper cyanides . . . . .	505
Recognition of copper cyanides; Zinc cyanide (hydrocyanate of zinc, prussiate of zinc) and its recognition; Silver cyanide (prussiate or hydrocyanate of silver); Potassium ferro-cyanide (yellow prussiate of potash) . . . . .	506
Recognition of potassium ferro-cyanide . . . . .	507

*VI. Carbonates.*

Potassium carbonate (potash) and its recognition; Acid potassium car- bonate or monopotassic carbonate, commonly called bicarbonate of potash; Sodium carbonate (washing soda) . . . . .	507
Sodium bicarbonate (baking powder); Calcium carbonate (marble, chalk); Copper carbonate and its recognition; Zinc carbonate . . . . .	508

Recognition of zinc carbonate; Nickel carbonate and its recognition; Cobalt carbonate . . . . .	509
--	-----

### VII. Sulphates and Sulphites.

Sodium sulphate (Glauber's salt); Ammonium sulphate and its recognition; Ammonium-potassium sulphate (potash-alum) . . . . .	509
Recognition of ammonium-potassium sulphate; Ammonium-alum and its recognition; Ferrous sulphate (sulphate of iron, protosulphate of iron, copperas, green vitriol) and its recognition; Iron-ammonium sulphate; Copper sulphate (cupric sulphate, blue vitriol or blue copperas) . . . . .	510
Recognition of copper sulphate; Cuprous sulphite; Zinc sulphate (white vitriol) and its recognition; Nickel sulphate . . . . .	511
Recognition of nickel sulphate; Nickel-ammonium sulphate; Cobalt sulphate and its recognition . . . . .	512
Cobalt-ammonium sulphate; Sodium sulphite and its recognition; Sodium bisulphite . . . . .	513

### VIII. Nitrates.

Potassium nitrate (saltpetre, nitre) and its recognition . . . . .	513
Sodium nitrate (cubic nitre or Chili saltpetre); Mercurous nitrate; Mercuric nitrate (nitrate of mercury) and its recognition; Silver nitrate (lunar caustic) . . . . .	514
Recognition of silver nitrate . . . . .	515

### IX. Phosphates and Pyrophosphates.

Sodium phosphate and its recognition; Sodium pyrophosphate and its recognition; Ammonium phosphate . . . . .	515
--	-----

### X. Salts of the Organic Acids.

Potassium bitartrate (cream of tartar); Potassium-sodium tartrate (Rochelle or Seignette salt) and its recognition; Antimony-potassium tartrate (tartar emetic) and its recognition; Copper acetate (verdigris). . . . .	516
Lead acetate (sugar of lead) and its recognition; Sodium citrate . . . . .	517

### B. VARIOUS APPARATUS AND INSTRUMENTS.

Glass balloons and flasks; Evaporating dishes or capsules . . . . .	517
Glass jars; Crucibles; Hydrometers . . . . .	518
Table showing the readings of different hydrometers . . . . .	519
Filters . . . . .	520
Siphons . . . . .	521
Stirring rods . . . . .	522



## APPENDIX.

## USEFUL TABLES.

Table of elements with their symbols, atomic weights and specific gravities . . . . .	523
Table of chemical and electro-chemical equivalents; Explanation of the table . . . . .	524
Table showing the value of equal current volumes as expressed in ampères per square decimetre, per square foot, and per square inch of electrode surface; Explanation of the table . . . . .	525
Table showing the specific electrical resistances of different sulphuric acid solutions at various temperatures; Table showing the specific electrical resistances of different copper sulphate solutions at various temperatures . . . . .	526
Table of the electro-motive force of elements . . . . .	527
Table showing the solubility of various substances; Table showing the composition of the most usual alloys and solders . . . . .	528
Alloys . . . . .	529
Solders; Soft solder; Hard solder; Silver solder . . . . .	530
Gold solder; Table of the melting points of some metals; Table of high temperatures; Table of the specific gravity and content of solutions of potassium carbonate at 57.2° F. . . . .	531
Table showing the specific gravity of sulphuric acid at 59° F. . . . .	532
Table of the specific gravity and content of nitric acid; Table showing the specific gravity of sal ammoniac solutions at 66.2° F. . . . .	533
Table showing the electrical resistance of pure copper wire of various diameters; Resistance and conductivity of pure copper at different temperatures . . . . .	534
Table showing actual diameters in decimal parts of an inch corresponding to the numbers of various wire gauges . . . . .	535
Weight of iron, copper and brass wire and plates . . . . .	536
Rules for speed; To find speed of counter-shaft in accordance with main shaft and machine; To find diameter of pulley on the main shaft; To find diameter of pulley on counter-shaft carrying belt to machine; To find the speed of a machine . . . . .	537
Comparison of the scales of the Fahrenheit, Centigrade and Réaumur thermometers, and rules for converting one scale into another . . . . .	538
Index . . . . .	539

# ELECTRO-DEPOSITION OF METALS.

---

## I.

### HISTORICAL PART.

---

#### CHAPTER I.

##### HISTORICAL REVIEW OF ELECTRO-METALLURGY.

IN reviewing the history of the development of electrolysis, *i. e.*, the reduction of a metal or a metallic alloy from the solution of its salts by the electric current, the simple reduction which takes place by the immersion of one metal in the solution of another, may be omitted. This mode of reduction was well known to the alchemist Zozimus, who described the reduction of copper from its solutions by means of iron, while Paracelsus speaks of coating copper and iron with silver by simple immersion in a silver solution.

Before the discovery, in 1789, of contact-electricity by Luigi Galvani, there was nothing like a scientific reduction of metal by electricity; and only in 1799 did Alexander Volta, of Pavia, succeed in finding the true causes of Galvani's discovery. Galvani observed while dissecting a frog on a table, whereon stood an electric machine, that the limbs suddenly became convulsed by one of his pupils touching the crural nerve with the dissecting-knife at the instant of taking a spark from the conductor of the machine. The experiment was several times re-

peated, and it was found to answer in all cases when a metallic conductor was connected with the nerve, but not otherwise. He observed that muscular contractions were produced by forming a connection between two different metals, one of which was applied to the nerve, and the other to the muscles of the leg. Similar phenomena having been found to arise when the leg of the frog was connected with the electric machine, it could scarcely be doubted that in both cases the muscular contractions were produced by the same agent. From a course of experiments, Galvani drew the erroneous inference that these muscular contractions were caused by a fluid having its seat in the nerves, which through the metallic connections flowed over upon the muscles. Everywhere, in Germany, England and France, eminent scientists hastened to repeat Galvani's experiments, in the hope of discovering in the organism a fluid which they considered the vital principle; but it was reserved to Volta to throw light upon the prevailing darkness. In his repeated experiments this eminent philosopher observed that one circumstance had been entirely overlooked, namely, that in order to produce strong muscular contractions in the frog-leg experiment, it was absolutely necessary for the metallic connection to consist of two different metals coming in contact with each other. From this he drew the inference that the agent producing the muscular contractions was not a nerve-fluid, but was developed by the contact of dissimilar metals, and identical with the electricity of the electric machine.

This discovery led to the construction of what is known as the *pile of Volta*, or the *voltaic pile*. The same philosopher found that the development of electricity could be increased by building up in regular order a pile of pairs of plates of dissimilar metals, each pair being separated on either side from the adjacent pairs by pieces of moistened card-board or felt. On account of various defects of the voltaic pile, Cruikshank soon afterwards devised his well-known *trough battery*, which consisted of square plates of copper and zinc soldered together, and so arranged and fastened in parallel order in a wooden box,

that between each pair of plates a sort of trough was formed, which was filled with acidulated water.

Nicholson and Carlisle, on May 2, 1800, first decomposed water into hydrogen and oxygen by electrolysis; and, in 1801, Wollaston found that if a piece of silver in connection with a more positive metal, for instance, zinc, be put into copper solution, the silver will be coated over with copper, which coating will stand the operation of burnishing.

Cruikshank, in 1803, investigated the behavior of solutions of nitrate of silver, sulphate of copper, acetate of lead, and several other metallic salts, towards the galvanic current, and found that the metals were so completely reduced from their solutions by the current as to suggest to him the analysis of minerals by means of the electric current.

To Brugnatelli we owe the first practical results in electro-gilding. In 1805 he gilded two silver medals by connecting them by means of copper wire with the negative pole of the pile, and allowing them to dip in a solution of fulminating gold in potassium cyanide, while a piece of metal was suspended in the solution from the positive pole. He also observed that the positive plate, if it consisted of an oxidizable metal, was dissolved.

One of the greatest discoveries connected with the subject, however, is that of Sir Humphry Davy, made October 6, 1807, when, by the decomposition of the alkalies by means of the electric current, he discovered the metals potassium and sodium.

Prof. Oersted, of Copenhagen, in 1820, found that the magnetic needle is deflected from its direction by the electric current. It was known long before this that powerful electric discharges affect the magnetic needle. It had, for instance, been observed that the needle of a ship's compass struck by lightning had lost its property of indicating the North Pole, and several physicists, among them Franklin, had succeeded in producing the same phenomena by heavy discharges of the electrical machine, but they were satisfied with the supposition that the electric current acted mechanically, like the blow of a



hammer. Oersted first perceived that electricity must be in a state of motion in order to act upon magnetism. This led to the construction of the galvanoscope or galvanometer, an instrument which indicates whether the elements or other source of current furnish a current or not, and by which the intensity of the source of current may also to a certain degree be recognized.

Ohm, in 1827, discovered the law named after him, that *the strength of a continuous current is directly proportional to the difference of potential or electro-motive force in the circuit, and inversely proportioned to the resistance of the circuit.* This law will be more fully discussed in the theoretical part.

Ohm's discovery was succeeded, in 1831, by the important discovery of *electric induction* by Faraday. By induction is understood the production of an electric current in a closed circuit which is in the immediate neighborhood of a current-carrying wire. Faraday further found that the current induced in the neighboring wire is not constant, because after a few oscillations the magnetic needle returned to the position occupied by it before a current was passed through the current-carrying wire; whilst, when the current was broken, the needle deflected in the opposite direction.

In the year following the discovery of Faraday, Pixii, of Paris, constructed the *first electro-magnetic induction machine.*

Faraday's electrolytic law of the proportionality of the current-strength and its chemical action, and that the quantities of the various substances which are reduced from their combinations by the same current are proportional to their chemical equivalents, was laid down and proved in 1833, and upon this Faraday based the measurement of the current-strength by chemical deposition, as, for instance, that of water, in the voltmeter.

Of the practical electro-chemical discoveries there remain to be mentioned the production of iridescent colors, in 1826, by Nobili, and the production of the amalgams of potassium and sodium, in 1853, by Bird.

The actual galvanoplastic process, however, dates from 1838. In the spring of that year Prof. Jacoby announced to the Academy of Sciences of St. Petersburg, a description of his discovery of the utility of galvanic electricity as a means of reproducing objects of metal. Hence Jacoby must be considered the father of galvanoplasty in as far as he was the first to utilize and give practical form to the discoveries made up to that time. Though Jacoby's process was published in the English periodical, "The Athenæum," of May 4, 1839, Mr. T. Spencer, who read a paper on the same subject, September 13, 1839, before the Liverpool Polytechnic Society, claimed priority of invention, as was also done by Mr. C. J. Jordan, who, on May 22, 1839, sent a letter to the "London Mechanical Magazine," which was published on June 8, 1839.

From this time forward the galvanoplastic art made rapid progress, and by the skill and enterprise of such men as the Elkingtons, of Birmingham, and De Ruolz, of Paris, it was speedily added to the industrial arts.

Though copies of a metallic object by means of galvanoplasty could now be made, the employment of the process was restricted to metallic objects of a form suitable for the purpose, until, in 1840, Murray succeeded in making non-metallic surfaces conductive by the application of graphite (black lead, plumbago), which rendered the production of galvanoplastic copies of wood-cuts, plaster-of-Paris casts, etc., possible.

Dr. Montgomery, in 1843, sent to England samples of gutta-percha, which was soon found to be a suitable material for the production of negatives of the original models to be reproduced by galvanoplasty.

Though it was now understood how to produce heavy deposits of copper, those of gold and silver could only be obtained in very thin layers. Scheele's observations on the solubility of the cyanide combinations of gold and silver in potassium cyanide, led Wright, a co-worker of the Elkingtons, to employ, in 1840, such solutions for the deposition of gold and silver, and it was found that deposits produced from these solutions

could be developed to any desired thickness. The use of solutions of metallic cyanides in potassium cyanide prevails at the present time, and the results obtained thereby have not been surpassed by any other practice.

From the same year also dates the patent for the deposition of nickel from solution of nitrate of nickel, which, however, did not attract any special attention. This may have been chiefly due to the fact that the deposition of nickel from its nitrate solution is the most imperfect and the least suitable for the practice.

To Mr. Alfred Smee we owe many discoveries in the deposition of antimony, platinum, gold, silver, iron, lead, copper, and zinc. In publishing his experiments, in 1841, he originated the very appropriate term "electro-metallurgy" for the process of working in metals by means of electrolysis.

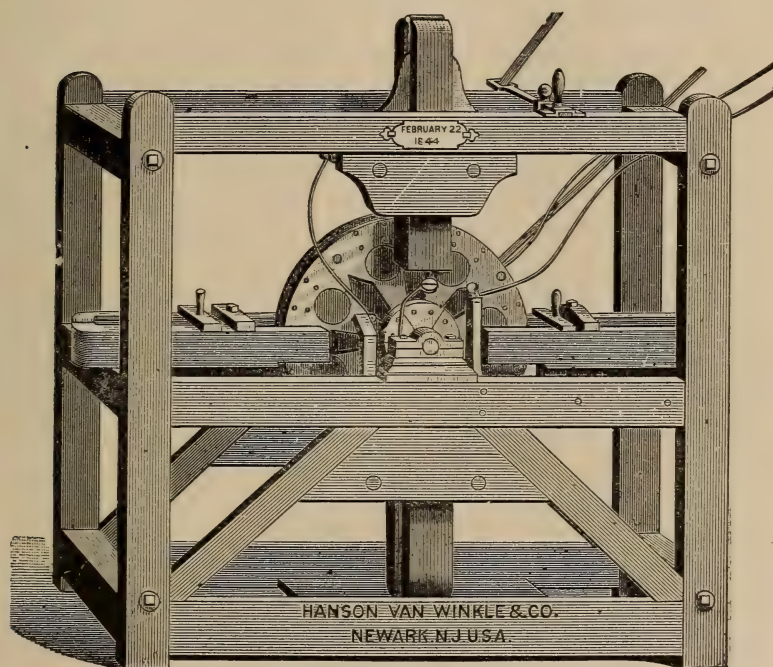
Prof. Böttger, in 1842, pointed out that dense and lustrous depositions of nickel could be obtained from its double salt, sulphate of nickel with sulphate of ammonium, as well as from ammoniacal solution of sulphate of nickel; and that such deposits, on account of their slight oxidability, great hardness, and elegant appearance, were capable of many applications. However, Böttger's statements fell into oblivion, and only in later years, when the execution of nickeling was practically taken up in the United States, his labors in this department were remembered in Germany. To Böttger we are also indebted for directions for coating metals with iron, cobalt, platinum, and various patinas.

In the same year, De Ruolz first succeeded in depositing metallic alloys—for instance, brass—from the solutions of the mixed metallic salts. In 1843, the first use of thermo-electricity appears to have been made by Moses Poole, who took out a patent for the use of a thermo-electric pile instead of a voltaic battery for depositing purposes.

From this time forward innumerable improvements in existing processes were made; and also the first endeavors to apply Faraday's discoveries to practical purposes.

The invention of depositing metals by means of a permanent current of electricity obtained from steel magnets was perfected and first successfully worked by Messrs. Prime & Son, at their large silverware works, Birmingham, England, and the original machine, constructed by Woolrych in 1844—the first magnetic machine that ever deposited silver on a practical scale—is still preserved at their works in its original position as a valuable

FIG. 1.



and interesting relic. The Woolrych machine stands 5 feet high, 5 feet long, and  $2\frac{1}{2}$  feet wide. An illustration of this original electro-plating machine, kindly furnished us by the Hanson & Van Winkle Co., of Newark, N. J., is given in Fig. 1.

As early as 1854, Christoffe & Co. endeavored to replace their batteries by magneto-electrical machines, and used the Holmes type, better known as the Alliance Machine, which, how-



ever, did not prove satisfactory; and besides, the prices of these machines were, in comparison with their efficacy, exorbitant. The machine constructed by Wilde proved objectionable on account of its heating while working, and the consequent frequent interruptions in the operations.

In 1860 Dr. Antonie Pacinotti, of Pisa, suggested the use of an iron ring wound around with insulated wire, in place of the cylinder. This ring, named after its inventor, has, with more or less modifications, become typical of many machines of modern construction. In the construction of all older machines, steel magnets had been used, and their magnetism not being constant, the effect of the machine was consequently also not constant. Furthermore, they generated alternately negative and positive currents, which, by means of commutators, had to be converted into currents of the same direction; and this, in consequence of the vigorous formation of sparks, caused the rapid wearing out of the commutators.

These defects led to the employment of continuous magnetism in the iron cores of the electro-magnets, the first machine based upon this principle being introduced in 1866, by Siemens, which, in 1867, was succeeded by Wheatstone's.

However, the first useful machine was introduced in 1871, by Zénobe Gramme, who in its construction made use of Pacinotti's ring. This machine was, in 1872, succeeded by Hefner-Alteneck's, of Berlin. In both machines the poles of the electro-magnet exert an inducing action only upon the outer wire wrappings of the revolving ring, the other portions being scarcely utilized, which increases the resistance and causes a useless production of heat. This defect led to the construction of flat-ring machines, in which the cylindrical ring is replaced by one of a flat shape, and of a larger diameter, thus permitting the induction of both flat sides. Such a machine was, in 1884, built by Siemens & Halske, of Berlin; and in the same year by S. Schuckert, of Nürnberg. In Schuckert's modern machines nearly three-quarters of all the wire wrappings are under the inducing influence of both of the large pole shoes of the electro-magnets.

Of European constructions of dynamo-electrical machines may be mentioned Mather's, Elmore's, Fein's, Krottlinger's, Naglo's, Reutlinger's, Lahmeyer's, Pöschmann & Co., and Dr G. Langbein & Co.'s. In this country Weston's machine and the dynamos manufactured by the Hanson & Van Winkle Co., of Newark, N. J., the Zucker & Levett Chemical Co., of New York, and others are largely used for electro-plating purposes.

For the sake of completeness, there may be mentioned the investigators and practitioners who during the last twenty years have contributed much to the improvement of the electro-chemical processes and the perfection of galvanoplasty. Besides those already named, they are: Elkington, Becquerel, Heeren, Roseleur, Elsner, von Leuchtenberg, Meidinger, Weil, Goode, Christofle, Klein, von Kress, Thompson, Adams, Gaiffe and others.

## II.

# THEORETICAL PART.

---

### CHAPTER II.

#### MAGNETISM AND ELECTRICITY

##### I. MAGNETISM.

FOR the better understanding of the electrolytic laws it will be necessary to commence with the phenomena presented by magnetism, and to consider them somewhat more closely.

A particular species of iron ore is remarkable for its property of attracting small pieces of iron and causing them to adhere to its surface. This iron ore is a combination of ferric oxide with ferrous oxide ( $\text{Fe}_3\text{O}_4$ ), and is called loadstone or magnetic iron ore. Its properties were known to the ancients, who called it magnesian stone, after Magnesia, a city in Thessaly, in the neighborhood of which it was found. If a natural loadstone be rubbed over a bar of steel, its characteristic properties will be communicated to the bar, which will then be found to attract iron filings like the loadstone itself. The bar of steel thus treated is said to be magnetized, or to constitute an artificial magnet. The artificial magnets thus produced may be straight, in the shape of a horse-shoe, or annular; but no matter what their form may be, there will always be two regions where the attractive force reaches its maximum, while between these two points there is a region which has no attractive effect whatever upon iron filings. As a rule, the two ends of the magnet show the greatest attractive force, and they are called the *magnetic*

*poles*, whilst the line running around the magnet, which possesses no attractive force, is termed the *neutral line* or *neutral zone*. In a closed magnet the poles are situated on the ends of one and the same diameter, while the neutral zones are located on the ends of a diameter standing perpendicular to the first.

When a magnetized bar or natural magnet is suspended at its centre in any convenient manner, so as to be free to move in a horizontal plane, it is always found to assume a particular direction with regard to the earth, one end pointing nearly north and the other nearly south. If the bar be removed from this position it will tend to reassume it, and after a few oscillations, settle at rest as before. The direction of the magnetic bar, *i. e.*, that of its longitudinal axis, is called the *magnetic meridian*, while the pole pointing towards the north is usually distinguished as the *north pole* of the bar, and that which points southward as the *south pole*.

A magnet, either natural or artificial, of symmetrical form, suspended in the presence of a second magnet, serves to exhibit certain phenomena of attraction and repulsion, which deserve particular attention. When a north pole is presented to a south pole, or a south pole to a north pole, attraction ensues between them, the ends of the bar approaching each other, and, if permitted, adhering with considerable force. When, on the other hand, a north pole is brought near a second north pole, or a south pole near another south pole, mutual repulsion is observed, and the ends of the bar recede from each other as far as possible. *Poles of an opposite name attract, and poles of a similar name repel each other.*

According to the theory or hypothesis proposed by Ampère, magnetism is caused by the presence of electric currents in the ultimate particles of matter. This theory assumes—

1. That the ultimate particles of all magnetizable bodies have closed electric circuits in which electric currents are continually flowing.

2. That in an unmagnetized body these circuits neutralize one another, because they have different directions.



3. That the act of magnetization consists in such a polarization of the particles as will cause these currents to flow in one and the same direction, *magnetic saturation* being reached when all the separate circuits are parallel to one another.

4. That *coercive force* is due to the resistance these circuits offer to a change in the direction of their planes.

Guided by these considerations, Ampère produced a coil of wire, called a *solenoid*, which is the equivalent of the magnetizing circuit assumed by his theory. It therefore follows that an electric current sent through a coil of insulated wire surrounding a rod or bar of soft iron, or other readily magnetizable material, will make it a magnet. A magnet so produced is called an electro-magnet; the magnetizing coil is called a helix, or solenoid. The polarity of the magnet depends on the direction of the current, or on the direction of winding of the helix or solenoid. The improbability of an electric current continually flowing in a circuit without the expenditure of energy, has led many scientific men to reject Ampère's theory of magnetism.

If an iron or steel needle be suspended free in the neighborhood of a magnet, it assumes a determined direction according to its greater or smaller distance from the poles or from the neutral zone. However, before the needle assumes this direction it swings rapidly with a shorter stroke, or slowly with a longer stroke, according to the greater or smaller attractive force exerted upon it. The space within which the magnetic action of a magnet is exercised is called the *magnetic field*, and the magnetic, as well as the electric, attractions and repulsions are, according to Coulomb, as the densities of the fluids acting upon each other, and inversely as the square of their distance.

## 2. ELECTRICITY.

In an ordinary state solid bodies exhibit no attractive effect upon small light particles, such as strips of paper, balls of elder-pith, etc.; but many solid bodies on being rubbed with a piece of dry cloth or fur acquire the property of attracting such light

bodies as mentioned above. The cause of this phenomenon is called *electricity*, and the bodies which possess this property of becoming electric by friction are termed *idio-electrics*, and those which do not appear to possess it, *non-electrics*. Gray, in 1727, found that all non-electric bodies conduct electricity, and hence are conductors, while those which become electric by friction are non-conductors of electricity. Strictly speaking, there are no non-conductors, because the resins, silk, glass, etc., conduct electricity, though only very slightly. It is therefore better to distinguish *good* and *bad* conductors. To test whether a body belongs to the idio-electrics, the so called electroscope is used, which in its simplest form consists of a glass rod mounted on a stand, and bent at the top into a hook, from which hangs by a silken thread or hair a pith ball. If, on bringing the rubbed body near the pith ball, the latter is attracted, the body is electric; whilst if the ball is not attracted, the body is either non-electric or its electricity is too slight to produce an attractive effect.

From the following experiments it was found that there exist *two* kinds of electricity: When a rubbed rod of glass or shellac is brought near the ball of elder-pith suspended to a silk thread, the ball is attracted, touches the rod, adheres for a few moments and is then repulsed. This repulsion is due to the fact that the ball by coming in contact with the rod becomes itself electric, and its electricity must first be withdrawn by touching with the hand before it can again be attracted by the rod. By now taking two such balls, one of which has been made electric by touching with a glass rod, which had been rubbed with silk, and the other by touching with a shellac rod rubbed with cloth, it will be observed that the ball, which is repulsed by the glass rod, is attracted by the shellac rod, and *vice versa*. These two kinds of electricity are called *vitreous* or *positive*, and *resinous* or *negative* electricity, and it has been found that *electricities of a similar name attract, and electricities of an opposite name repel each other*.

For want of a concrete knowledge of the electric agent which

produces the electric phenomena, various theories or hypotheses have been advanced to explain these phenomena and the action of the electric forces. Only two of the best known theories or hypotheses shall here be mentioned.

*Double fluid hypothesis of electricity.* By this hypothesis it is endeavored to explain the causes of electric phenomena by the assumption of the existence of two different electric fluids.

The double fluid hypothesis assumes:—

1. That the phenomena of electricity are due to two tenuous and imponderable fluids, the positive and the negative.
2. That the particles of the positive fluid repel one another, as do also the particles of the negative fluid; but that the particles of the positive fluid attract the particles of the negative, and *vice versa*.
3. That the two fluids are strongly attracted by matter, and when present in it produce electrification.
4. That the two fluids attract one another and unite, thus masking the properties of each.
5. That the act of friction separates these fluids, one going to the rubber and the other to the thing rubbed.

*Single fluid hypothesis of electricity.* By this hypothesis it is endeavored to explain the cause of electric phenomena by the assumption of the existence of a single electric fluid.

The single fluid hypothesis assumes:—

1. That the phenomena of electricity are due to the presence of a single, tenuous, imponderable fluid.
2. That the particles of this fluid mutually repel one another, but are attracted by all matter.
3. That every substance possesses a definite capacity for holding the assumed electric fluid, and that when this capacity is just satisfied, no effects of electrification are manifest.
4. That when the body has less than this quantity present, it becomes *negatively excited*, and when it has more, *positively excited*.
5. That the act of friction causes a redistribution of the fluid, part of it going to one of the bodies, giving it a surplus, thus

positively electrifying it, and leaving the other with a deficit, thus negatively electrifying it.

However, the epoch-making investigations of Prof. Herz, of Bonn (1889), have led to different views regarding the nature of electricity. Herz has shown by experiments that electricity is transmitted in space by waves, like heat and light, and he has determined the length and velocity of electrical waves. From this it has been ascertained that electricity is founded upon motion, and that the current appearing in a conductor has to be referred to vibrations of the molecules forming the conductor, relatively to vibrations of the *ether* enveloping the molecules. By the term ether is designated the imponderable medium pervading all space. Hence electricity is an energy, just the same as light and heat are manifestations of energy.

According to Coulomb, *the electric attractions and repulsions are as the densities of the fluids acting upon each other, and inversely as the square of the distance.*

However, a current of electricity is created not only by friction, but also by the contact of various metals. In the same manner as the copper and iron in Galvani's experiments with the frog-leg, other metals and conductors of electricity also become electric by contact, the electric charges being, however, stronger or weaker, according to the nature of the metals. If zinc be brought in contact with platinum, it becomes more strongly positively electric than when in contact with copper; whilst, however, copper in contact with zinc is negatively excited, in contact with platinum it becomes positively electric. By now arranging the metals in a series, so that each preceding metal becomes positively electric in contact with the succeeding one, a *series of electro-motive force or tension* is obtained, in which the metals or conductors of electricity stand as follows:

+ Zinc, cadmium, tin, iron, lead, copper, nickel,  
Silver, antimony, gold, platinum, carbon—.

While two metals of the series of electro-motive force or tension touching each other become electrically excited in such a manner



that one becomes positively and the other negatively electric, an exchange of the opposite electricities takes place by introducing a conducting fluid between the metals. Thus, if a plate of zinc and a plate of copper connected by a metallic wire are immersed in a conducting fluid, for instance, dilute sulphuric acid, the electricity of the positive zinc passes through the fluid to the negative copper, and returns through the wire—the *closed circuit*—to the zinc. However, in the same degree with which the electricities equalize themselves, new quantities of them are constantly formed on the points of contact of the metals with the conducting fluid; and, hence, the flow of electricity is continuous. This electric current generated by the contact of metals and fluids is called the *galvanic current*; or, since it is generated by the intervention of fluid conductors, *hydro-electric current*. A combination of conductors which yields such a galvanic current, is called a *galvanic element* or *galvanic chain*.

It would here be the place to discuss the various galvanic elements, but it is thought better to describe them in a separate chapter, and first to explain the laws and the actions of the galvanic current.

*Electrical potential*.—The property of electricity corresponding to *head* or *pressure*, as applied in speaking of gas or water-power, is termed the *electrical potential*. Two bodies have the same electrical potential when, connected by a metallic wire, they develop no electricity.

*Electro-motive force*.—If, however, two bodies connected by a metallic wire possess unequal electrical potentials, a movement of the electricity takes place, and the force which produces this movement or current is called the *electro-motive force* or *tension*. It, therefore, corresponds to the difference of the potentials; and the magnitude of this difference of the potentials is the measure for the *electro-motive force*.

*Resistance*.—All conductors offer a certain amount of resistance to the forward movement of the electric current. By connecting, for instance, two bodies charged with electricity and possessing a difference of potentials, by a metallic conductor, a

certain time is required for the compensation of the difference of potentials, or, in other words, before the electrical equilibrium is established. By now keeping the difference of potentials constant, the quantity of electricity which passes through the closed conductor—the closed circuit—depends on the resistance which the latter offers to the passage of the current.

*The resistance of a conductor is proportional to its length and inversely to its cross-section and its conducting capacity; i. e., the longer the conducting circuit the greater the resistance, and the greater its cross-section the smaller the resistance.* Wires of small diameter will, therefore, offer greater resistance to the current than those with larger diameter, and wires with good conducting capacity will produce less resistance than those with poor conducting capacity. According to Lazarus Weiler, the conducting power of metals is in declining order as follows: Silver, chemically pure copper, gold, silicon bronze, commercial copper, aluminium, zinc, brass, tin, steel, platinum, lead, nickel, antimony.

*Quantity of current. Ohm's law.*—The quantity of electricity, or, in other words, the current strength, which an element furnishes at a determined extreme point, depends on the strength of the electro-motive force which impels the current, as well as on the resistance which the conductor offers to the current. In the preceding it has been seen that the electro-motive force corresponds to the difference of the potentials of two conductors connected by a metallic wire; the greater this difference is, the greater the energy with which the compensation of the electricities takes place. It has also been explained that the resistance increases in proportion to the length, and decreases with the increase in the cross-section of the conductor. Upon these relations Ohm's law is based, and in its completeness it may be summed up as follows: *The quantity of electricity or the strength (intensity) of current is directly proportional to the sum of the electro-motive forces of the exciting elements, and is inversely proportional to the sum of the resistances of its closed circuit; however, the resistance of each part of the closed circuit*

is proportional to its length and inversely proportional to its cross-section. Now, if  $S$  indicates the strength of current,  $E$  the sum of the electro-motive forces, and  $L$  the total resistance, then the strength of current  $S$  is—

$$S = \frac{E}{L}.$$

The total resistance  $L$  is, however, composed of two different resistances, namely, of the so-called *essential* or *internal* resistance, which expresses the resistance of the substances in the elements themselves, and of the *non-essential* or *external* resistance of the closed circuit. If, therefore, the internal resistance  $= R$  and the external resistance  $= r$ , the total resistance will be  $L = R + r$ , and the formula given above is changed to

$$S = \frac{E}{R + r}.$$

Let us now examine the useful applications which result from Ohm's law, to the coupling of the elements, they being of great importance to the practical electro-plater. According to the above formula, which expresses the total performance of a battery, the strength of current of a single element is, if  $s$  indicates its current strength,  $e$  the electro-motive force,  $R$  the essential or internal resistance, and  $r$  the resistance in the closed circuit,

$$s = \frac{e}{R + r}.$$

By now uniting several such elements, let us say  $n$  elements, to a column, the electro-motive force of the latter has become  $n + e = ne$ , and the internal resistance  $nr$ . With the same closed circuit as that of the single element,  $r$  will not increase, hence the strength of these  $n$  elements must be written—

$$S = \frac{ne}{nR + r}$$

It is now clear that when a determined closed circuit of the resistance  $r$  is given, the strength of current cannot be indefinitely augmented by increasing the number of  $n$  elements; because, though the electro-motive force, by the augmentation

of  $n$  elements, increases by so many  $n$ , the internal resistance  $R$  also grows, so that finally the value  $r$ , which remains constant, disappears, contrary to the resistance  $R$ , which increases  $n$  times. Hence, the strength of current constantly approaches more the limit of value—

$$\frac{n e}{n R} = \frac{e}{R}.$$

On the other hand, the effect can neither be increased by enlarging the area of the pair of plates nor by decreasing the resistance of the fluid in a given number of elements. Because when  $r$ , the external resistance, is sufficiently large so that the internal resistance,  $n R$ , may be neglected, the intensity always approaches more the value  $\frac{e}{r}$ .

Hence, it follows *that the augmentation of the area of the exciting pair of plates produces an increase in the current-strength only when the external resistance in the closed circuit is small in proportion to the internal resistance of the battery.*

If we now apply the results of the above explanations to practice, we find that the elements may be coupled in various ways according to requirement.

1. If, for instance, four Bunsen elements (carbon-zinc) are coupled *one after another* in such a manner that the zinc of one element is connected with the carbon of the next, and so on

FIG. 2.

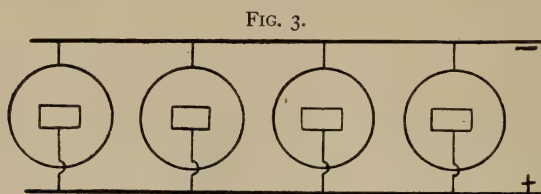


(Fig. 2), the current passes four times in succession through an equally large layer of fluid, in consequence of which the internal resistance,  $4 R$ , is four times greater than that of a single element, while the resistance of the closed circuit,  $r$ , remains the same. Hence, while the current-strength is thereby not increased, the electro-motive force is, and for this reason this



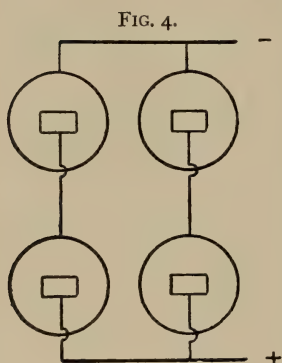
mode of coupling is called the *union* or *coupling of the elements for electro-motive force or tension*.

2. By connecting four elements *alongside of each other, i. e.*, all the zinc plates and all the carbon plates one with another



(Fig. 3), the current simultaneously passes through the same layer of fluid in four places; the internal resistance of the battery is therefore the same as that of a single element, and since the area of the plates is four times larger than that of a single

element, the quantity of current is augmented by this mode of coupling. This is called *coupling for quantity of current*.



3. Two elements may, however, be connected for electro-motive force or tension, and several such groups coupled alongside of each other as shown in Fig. 4, whereby, according to what has above been said, the electro-motive force as well as the current strength is augmented. This mode of

connection is called *mixed coupling*.

According to the resistance of the bath, as well as of the exterior closed circuit, and the surfaces to be plated, the electro-plater may couple his elements in either way, and in speaking later on of the elements the various modes of coupling will be further discussed. We will here only mention the proposition deduced from Ohm's law, that *a number of galvanic elements yield the maximum of intensity of current when they are so arranged that the internal resistance of the battery is equal to the*

*resistance in the closed circuit.* Hence, when operating with baths of good conductivity and slight resistance, for instance acid copper baths, silver cyanide baths, etc., with a slight distance between the anodes and the objects, and with a large anode-surface, it will be advantageous to couple the elements *alongside of each other for quantity.* However, for baths with greater resistance and with a greater distance of the anodes from the objects, and with a smaller anode surface, it is best to couple the elements *one after the other for electro-motive force or tension.*

The effects of the electric current are thermal, physiological, electro-magnetic, inductive, and chemical; however, for our purposes, only the last three need be discussed.

#### *Electro-magnetism.*

If a wire conveying the electric current be brought near a magnetic needle, the latter will immediately be deflected from its direction, no matter whether the wire conveying the current be placed alongside, above, or beneath the magnetic needle. The direction which the needle will assume when placed in any particular position to the conducting wire, may be determined by the following rule: *Let the current be supposed to pass through a watch from the face to the back: the motion of the north pole will be in the direction of the hands.* Or, *let the observer imagine himself swimming in the direction of the current with his face towards the needle: the north pole of the needle will then be deflected towards his left hand.*

When the needle is subjected to the action of two currents in opposite directions, the one above and the other below, they will obviously concur in their effects. The same thing happens when the wire carrying the current is bent upon itself and the needle placed between the two portions; and since every time the bending is repeated a fresh portion of the current is made to act in the same manner upon the needle, it is easy to see how a current, too feeble to produce any effect when a simple straight wire is employed, may be made by this contrivance to exhibit

a powerful action on the magnet. It is on this principle that instruments called *galvanoscopes*, *galvanometers*, or *multipliers* are constructed. They serve not only to indicate the existence of electrical currents, but also to show by the effects upon the needle the direction in which they are moving. The delicacy of the instrument has been increased by Nobili through the use of a very long coil of wire, and by the addition of a second needle. This instrument is known as the *astatic galvanometer*. The two needles are of equal size and magnetized as nearly as possible to the same extent. They are then immovably fixed together parallel and with their poles opposed, and hung by a long fibre of untwisted silk, with the lower needle in the coil and the upper one above it. The advantage thus gained is twofold: The system is *astatic*, unaffected, or nearly so, by the magnetism of the earth; and the needles being both acted upon in the same manner by the current, are urged with much greater force than one alone would be, all the actions of every part of the coil being strictly concurrent. A divided circle is placed below the upper needle, by which the angular motion can be measured, and the whole is inclosed in glass, to shield the needles from the agitation of the air.

The deflection of the magnetic needle by the electric current has led to the construction of instruments which allow of the intensity of the current being measured by the magnitude of the deflection. Such instruments are, for instance, the *tangent galvanometer*, the *sine galvanometer*, etc., but they are almost exclusively used for scientific measurements, while for the determination of the intensity of current for electro-plating purposes other instruments are employed, which will be described later on. However, the electric current exerts not only a reflecting action on magnetic needles, but is also capable of producing a magnetizing effect on iron and steel. If a bar of iron be surrounded by a coil of wire, covered with silk or cotton for the purpose of insulation, it becomes magnetic so long as the current is conducted through the coil. Such iron bars converted into temporary magnets by the action of the current are

called *electro-magnets*, and they will be more highly magnetic the greater the number of turns of the coil, and the more intense is the current passing through the turns.

However, not only the iron bar, around which the current circulates, becomes magnetic, but also a conducting wire through which passes a strong current. By suspending a circular conducting wire so that it is free to move around its vertical axis, its direction is affected by the magnetism of the earth, and it will take up a position so that its plane stands at a right angle to the plane of the magnetic meridian. By now conducting the current through a wire having the form of a long helix, a so-called *solenoid*, the wire will, in a like manner, place itself with the turns of the helix at right angles to the plane of the magnetic meridian, or, in other words, the axis of the solenoid will lie in the magnetic meridian.

In the same manner as an electrified conducting wire acts upon a magnet, two electrified wires exert an attracting and repelling influence on each other, the general law of the action being that *electric currents moving in parallel lines attract one another if they move in the same direction, and repel one another if they move in opposite directions.*

### *Induction.*

By induction is understood the production of an electric current in a closed circuit which is in the immediate neighborhood of a current-carrying wire.

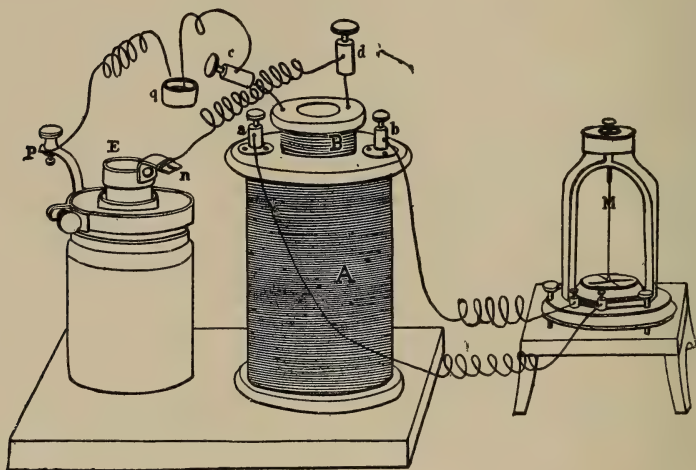
Suppose we have two insulated copper wire spirals, *A* and *B* (Fig. 5), *B* being of smaller diameter and inserted in *A*. When the two ends of *B* are connected with the poles of a battery a current is formed in *A* the moment the current of *B* is closed. This current is recorded by the deflection of the magnetic needle of a multiplier, *M*, which is connected with the ends of *A*, the deflection of the needle showing that the current produced in *A* by the current in *B* moves in an opposite direction. The current in *A*, however, is not lasting, because, after a few oscillations, the magnetic needle of the multiplier returns to its



previous position and remains there, no matter how long the current may pass through *B*. If, however, the current in *B* be interrupted, the magnetic needle swings to the opposite direction, thus indicating the formation of a current in *A*, which passes through it in the same direction as the interrupted current in *B*.

The current causing this phenomenon is called the *primary* or *inductive* current, and that produced by it in the closed circuit the *secondary, induced* or *induction* current. From what has been above said, it is clear that *an electric current at the*

FIG. 5.



*moment of its formation induces in a neighboring closed circuit a current of opposite direction, but when interrupted, a current of the same direction.*

In the same manner as closing and opening the inductive current, its sudden augmentation also effects the induction of a current of opposite direction in a neighboring wire, while its sudden weakening induces a current of the same direction; the same effect being also produced by bringing the inductive wire closer to, or removing it further from, the neighboring wire. The induced currents being alternately formed by opening and

closing the circuit, and they showing different directions, the term *alternating currents* has been applied to them.

If the windings of the spirals are very close together, each winding induces the other, the so-called *extra currents* being thereby formed.

The induced currents follow Ohm's law the same as the inductive current. A long inducing wire with a small cross-section offers greater resistance than a short wire with a larger cross-section, and consequently in the first case the current will possess slighter intensity and higher tension, and in the other greater intensity and less tension.

In the same manner as an electrified wire induces a current in a neighboring wire, a magnet or electro-magnet also produces induced currents in a coil of wire surrounding it. These currents act in the same manner as those produced by other means, and by taking into consideration Ohm's law, currents of great and slight intensity can be produced at will, as will be seen in speaking of the dynamo-electric machines, the construction of which is based upon the principle of induction.

#### *Chemical actions of the electrical current—Electrolysis.*

An electric current on being conducted through a fluid effects the reduction of its constituents. By cutting, for instance, the conductor of an electric current, and introducing the two wire ends thereby formed into water acidulated with dilute sulphuric acid, the water, provided the current is strong enough, is decomposed into its constituents, hydrogen and oxygen, the former separating in the form of gas on the negative pole and the latter on the positive. If such a decomposition does not take place, the fluid does not conduct the current. Pure water by itself is a bad conductor, and to make its decomposition possible it has to be made conductive by acidulation with dilute sulphuric acid. When a chemical composition is decomposed by the current, the constituent forming the basis of the combination separates on the negative pole, and that constituting the acid on the positive; hence metals and hydrogen are lib-

erated on the negative, and acids and oxygen on the positive, pole. To Faraday is due the discovery of the chemical actions of the current and the exposition of the laws governing the separation of the constituents. He adopted the term *electrolysis* for the electrical separation of chemical combinations, and *electrolyte* for the fluids subjected to electrical decomposition. To the poles or plates leading the current into and out of the electrolyte he applied the term *electrodes*, the positive pole being the *anode*, and the negative pole the *cathode*. The elements of the electrolyzed liquid, which are liberated by the action of the current, are termed *ions*, those set free on the anode or positive electrode being termed *anions*, and those at the cathode or negative anode *kations*. Thus, when acidulated water is electrolyzed, two ions are evolved, namely, oxygen and hydrogen, the former at the positive, and the latter at the negative, electrode.

It is absolutely necessary for the electrolyte to be in a fluid state, though it does not matter whether the fluid state is produced by solution or fusion.

We know no more of the actual cause of the chemical action of electricity than of its nature and origin. According to Clausius' theory, matter is composed of minute particles called molecules, which, though mechanically indivisible, are chemically divisible. The constituent parts of the molecules which are no further chemically divisible are called *atoms*. Clausius supposes that the molecules are in constant motion; that in solid bodies they move around definite positions of equilibrium, while in fluids even apparently tranquil they move from one place to another, constantly revolving and pushing against one another without being subjected to a return to their original positions. In pushing against one another the molecules are decomposed into the atoms of which they are composed. Those atoms, however, which have become electro-negative under the influence of the current, endeavor to reach the anode, while those which have become electro-positive move towards the cathode. But in doing this they meet atoms of opposite

polarity, with which they reunite to a molecule until they are again liberated by this molecule pushing against another, when they move further towards the anode. Arriving at the electrodes, they find no more atoms of opposite polarity with which they might unite to a molecule; both atoms, therefore, remain free on the electrodes, while the electrolyte between the two electrodes suffers no perceptible change. The atoms are, therefore, to be considered as ions. However, in order that the ions may be attracted by the electrodes, a current of determined electro-motive force is required; as otherwise, though the electrolyte may conduct the current, the atoms attract one another more vigorously than they are attracted by the electrode, and again form molecules. To this mutual attraction of the atoms of opposite polarity is due the resistance of the electrolyte to the transmission of the current, and also the formation of a current of an opposite direction to that of the primary current, which is called the *counter* or *polarizing current*.

However, since 1887, when Svante Arrhenius established his theory of electrolytic dissociation, Clausius's theory has been entirely abandoned. Svante shows that the salts when in aqueous solution are, according to the degree of dilution of the solution and the nature of the salts, more or less extensively dissociated into more proximate electrically charged constituents. This property of dissociating in this manner in solutions belongs, however, only to certain classes of bodies, namely acids, bases and soluble salts. Only those bodies which dissociate in solution are conductors of the electrical current and are called *electrolytes*, and the electrically charged constituents into which the bodies split, are called *ions*.

The ions are divided into two classes. By the action of the electric current upon the electrolytes, one class moves in the direction taken by the positive current, hence towards the negative electrode, on which it is separated, since according to the electrical theory, electricities of an opposite name attract and those of a similar name repel each other. Hence the ions



which travel towards the negative electrode must be positively charged and they are termed *kations*. The other ions which move in the direction of the negative current, hence towards the positive electrode, are negatively charged, and are called *anions*.

According to Oswald, the most important ions are as follows :

1. *Kations*:

- a. *Univalent*: Hydrogen, potassium, sodium, lithium, calcium, rubidium, thallium, silver, ammonium, copper (in cupro-combinations), mercury (in mercuro-combinations), gold, etc.
- b. *Bivalent*: Calcium, strontium, barium, magnesium, iron, etc.
- c. *Trivalent*: Aluminium, bismuth, antimony, etc.
- d. *Quadrivalent*: Tin, iridium.

2. *Anions*:

- a. *Univalent*: Hydroxyl (in bases), chlorine, iodine, bromine, fluorine,  $\text{NO}_3\text{ClO}_3\text{ClO}_4$ , besides the anions of all monobasic acids.
- b. *Bivalent*: Sulphur, selenium,  $\text{SO}_4$ , and the anions of the bibasic acids.
- c. *Trivalent*: The anions of the tribasic acids.

The ability of forming ions depends not only on the nature of the body, but also on the solvent, and this ability is termed power of dissociation. Water possesses the greatest power of dissociation, and the formation of ions increases with increased dilution of the solution.

The formation of ions may be effected in various ways, but it is most frequently the case that in dissolving salts electrically neutral molecules split into ions. But since in the solutions of the electrolytes, beside existing ions, there are present electrically neutral substances, the latter may entirely or partly withdraw the charge from the existing ions and thereby themselves be changed into the ion-state, while the discharged ions become either electrically neutral or pass into a condition with a smaller electrical charge. Furthermore, a substance may force a fur-

ther charge upon already existing ions, and thereby be changed into the ion-state.

As mentioned above, only bodies capable of dissociation conduct the current, and since dissociation increases with dilution, the conducting capacity must also increase up to the state of solution in which complete dissociation to ions takes place.

Owing to this movement of the positive ions to the negative pole, and of the negative ions to the positive pole, this phenomenon is termed the traveling of the ions, and the question arises whether the velocity with which the ions move is the same for all or not. By experiments Hittorfs has shown that the ions possess unequal traveling velocity, because the concentration and composition of the electrolytes, which were precisely similar before the action of the current on the anode and the cathode, showed differences after continued action of the current, an increase of the negative ion having taken place on the one hand, and a decrease of the positive ion on the other.

For the better understanding of this more modern theory it will be necessary to add a few more brief theoretical observations. Like gas, molecules exert upon the walls of the space confining them a pressure which is inversely proportional to the volume; solutions of substances also exert a pressure which is called *osmotic pressure*. However, this pressure cannot be directly recognized because it is fixed to the volume of the solvent, the surface of which acts like the rigid walls of the holder enclosing the gas. Owing to the surface-tension, *i. e.*, the tension of the surface-layers, in consequence of which the latter endeavor to become smaller, a pressure is exerted upon the interior of the solution which is inversely greater than the pressure directed against the surface of dissolved bodies. If, however, a porous vessel containing solution is placed in another vessel holding pure solvent, whereby the surface-tension on the walls of the porous vessel is relieved, the pressure of the solution, which endeavors to increase the volume, makes itself felt by the entrance of the solvent into the solution through the porous wall. By the selection of suitable membranes this diffu-

sion can be debarred so that the augmented volume of the solution contains the same quantity of the dissolved body as the previously more concentrated solution. If, on the other hand, there is a pressure in the solution which endeavors to decrease the volume, it is produced by the withdrawal of solvent from the porous vessel.

According to modern views, the formation of the polarizing current is explained as follows: Every atom which is separated by the electric current on the electrodes possesses a certain electrolytic solvent pressure which endeavors to reconstruct the separated atom as an ion into the electrolyte. This creates an electromotive counter-force opposed to the primary current, the latter being thereby weakened. The polarizing current follows the same laws as the primary current, and grows with the increasing intensity of the latter.

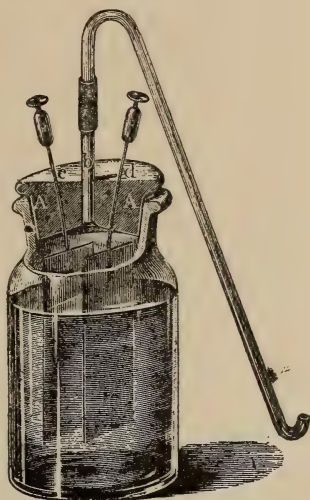
Now the primary current can pass through the electrolyte only when its electromotive force is greater than that of the polarizing current. If the decomposition of the electrolyte is induced by a weak primary current, the polarizing current may possess greater electromotive force, and the primary current must be strengthened for the decomposition of the electrolyte. The point at which the primary current just overcomes the polarizing current and continuous decomposition of the electrolyte is rendered possible is called the decomposition-point, and the resulting values for metallic solutions are termed decomposition-values. These vary for the several metallic salts, and this explains why from a solution containing different metals in the form of salts, the separate metals may be separated one after the other with a varying current-tension.

For the purposes of this treatise it would carry us too far to enter further into a purely scientific discussion of electrochemistry, and we now turn our attention to the electrolytic laws discovered by Faraday.

*First law. The quantity of substance separated within a determined time by the current is directly proportional to the strength of the current.* By conducting the current through a volt-

meter (Fig. 6), *i. e.*, a closed decomposing cell provided with two platinum electrodes, which are in contact with the poles of the element, and dip into acidulated water, oxygen evolves on the positive electrode and hydrogen on the negative. The gas mixture (oxyhydrogen gas) is conducted through a bent tube inserted air-tight in the stopper of the cell, into graduated tubes, in such a manner that the gas enters the tubes under water. The escaping mixture of gas rises in the form of bubbles into the upper part of the tube, and the volume of gas there collected in a determined time can be readily read off.

FIG. 6.



Now, if a current of determined strength has produced a determined quantity of oxyhydrogen gas in the voltmeter, a current twice as strong will, according to Faraday's law, produce in the same time double the volume of gas, from which further results the fact that for the decomposition of a determined quantity of any body, a constant quantity of current is always required, to which the term *electrical equivalent* might be applied.

*Second law.* If the same current acts upon a series of different solutions, the weights of the elements separated at the same time in each solution are proportional to their chemical equivalents. If, for instance, the same current be conducted through three decomposing cells, one of which contains water, the second a solution of blue vitriol, and the third a solution of nitrate of silver, for each gramme of hydrogen developed in the first cell, 31.75 grammes of copper will be separated in the second cell, and 108 grammes of silver in the third cell, because their chemical equivalents are as 1 : 31.75 : 108.

*Third law.* In an element, the chemical decomposition—the



*dissolution of zinc—is proportional to the strength of current; or, in other words, as many equivalents of zinc are dissolved in the element as equivalents of another metal are separated in an interposed electrolyte.* Every electro-plater observes that the zinc cylinders of the elements are dissolved; and it is just this solution which maintains the development of the electric current. As is well known, zinc is strongly attacked and dissolved by dilute sulphuric acid; therefore a dissolution of zinc takes place before the galvanic apparatus is closed. This dissolution of zinc, independent of the production of current, is termed *local action*, and to decrease it the zinc is amalgamated by first washing it with strong soda to remove grease. Then it is dipped into a vessel of water containing  $\frac{1}{10}$  of sulphuric acid. As soon as strong action takes place it is transferred to a suitable dish, mercury poured over it, and finally is rubbed till a bright silver-like film forms. It is then set up on edge to drain, and before use any globules set free are rubbed off. If local action has thus been prevented, only as much zinc will dissolve, according to this law, as is chemically equivalent to the metal separated in the decomposing cell. If, however, local action is present, the consumption of zinc is increased by the quantity corresponding to solution by local action.

*Electro-chemical equivalents.*—This term is applied to the weights of the various electrolytes which are decomposed in the unit of time by the electric unit. The electro-chemical equivalents are proportional to their chemical equivalents. The electro-chemical equivalent of a body is found by multiplying its chemical equivalent by the electro-chemical equivalent of hydrogen = 0.0001022.

When an electric current passes through a conductor, the latter becomes more or less heated. According to Joule's experiments, it was found that *the development of heat in the conductor is proportional to its resistance; and further, that it is proportional to the square of the strength of current.*

Hence the development of heat will be the greater the smaller the cross-section of the conductor and its conducting

capacity are, and the larger the quantity of current which passes through it. For practical purposes, the conclusion derived from this is the necessity of choosing conducting wire of good conducting capacity and of sufficiently large diameter to prevent the development of heat, which in this case means loss of current.

*Consumption of power in electrolysis.*—Without a desire further to enter into the details of the electro-chemical theory, it may for the sake of completeness be mentioned that *the force required for the decomposition of an electrolytic solution is at least equal to that which, when converted into heat, corresponds to the heat developed by the separated bodies in their reunion into their original combination.*

*Electric units.*—The electro-motive force required for the decomposition being frequently given, as well as the intensity which the current must possess in order properly to coat a determined surface of article with the electrolytically separated metal, the electric units serving for electric measures will be briefly given:

To measure the physical phenomena of the current it is necessary to refer to mass, length, and duration of time, and the units adopted by the International Congress of 1881 are as follows:—

1. Unit of length, 1 centimetre.
2. Unit of time, 1 second.
3. Unit of mass, the mass of one gramme.

The term *fundamental* or C. G. S. (centimetre-gramme-second) units has been applied to this system.

*Force or power (F)—Dyne.*—Force which acting upon 1 gramme for a second generates a velocity of 1 centimetre per second.

*Work—Erg.*—Amount of work done by 1 dyne working through 1 centimetre of distance.

*Quantity.*—The quantity conveyed by unit current in 1 second.

*Potential or electro-motive force.*—The difference of the electric

condition between two conductors or two points of a conductor, when the transference of electricity from one to the other is proceeding at the rate of 1 erg of work per unit of electricity transferred.

*Resistance*.—A resistance such that with unit of difference of potential between the ends of conductor, 1 unit of current is conveyed along it.

Of the so-called practical units, which were retained by the Congresses and Conferences of 1881 and 1884, there are five: the *ohm*, *volt*, *ampère*, *farad*, and *coulomb*.

The *ohm* is the practical unit of resistance. It is equal to the resistance of a column of mercury 1 metre long and 1 square millimetre in cross-sectional area at 0° C., and approximately equal to the resistance of 48.5 metres of pure copper wire, 1 millimetre in diameter, at 0° C. The ohm is equal to  $10^9$  C. G. S. units.

The *ampère* is the practical unit of the current-strength (intensity); it is equal to  $\frac{1}{10}$  of the theoretical C. G. S. unit. For practical purposes the quantity of silver precipitated in one second is taken as the representative value of an ampère, 0.0011188 gramme of silver corresponding, according to Kohlrausch, to one ampère.

The *volt* is the practical unit of the electro-motive force, and is equal to  $10^8$  C. G. S. units. It is approximately equal to the electro-motive force of a single Daniell's cell.

The *farad* is the practical unit of capacity equal to  $10^9$  C. G. S. units; the *coulomb* is the unit of quantity, *i. e.*, the volume of current equal to that of 1 ampère passing through a circuit for one second of time.

A current of 1 ampère at the pressure of 1 volt is termed a *watt*; it is a most useful unit for comparing different currents, and is really the product of volume into pressure.

The English horse-power (*H. P.*) is taken at 550 foot-pounds per second, and is thus equivalent to raising 550 pounds through one foot, or one pound through 550 feet, in a second. (The French *H. P.* is 542.48 foot-pounds per second.)

# III.

## SOURCES OF CURRENT.

---

### CHAPTER III.

#### GALVANIC ELEMENTS—THERMO-PILES—MAGNETO- AND DYNAMO-ELECTRIC MACHINES.

THE sources of current used for electro-deposition of metals are the *galvanic elements*, *thermo-piles*, *magneto-electric machines*, and *dynamo-electric machines*.

#### A. GALVANIC ELEMENTS.

It is not proposed to enter into a detailed description of all the forms of galvanic elements, because the number of such constructions is very large, while the number of those which have been successfully and permanently introduced for practical work is comparatively small.

The original form of the galvanic elements, the voltaic pile, consisting of zinc and copper plates separated from one another by moist pieces of cloth, has been already mentioned on p. 2, as well as its disadvantages, which led to the construction of the so-called *trough battery*. The separate elements of this battery are square plates of copper and zinc, soldered together and parallel, fixed into water-tight grooves in the sides of a wooden trough so as to constitute water-tight partitions, which are filled with acidulated water. The layer of water serves here as a substitute for the moist pieces of cloth in the voltaic pile.

In other constructions the fluid is in different vessels, each



vessel containing a zinc and a copper plate which do not touch one another in the same vessel, the copper plate of the one vessel being connected with the zinc plate of the next, and so on.

In all elements with one fluid as an excitant, the current is quite strong at first, but quickly decreases for the following reasons: First, during the interruption of the current, a change takes place in the fluid by the local action in the element, and then with a closed circuit the zinc with the impurities it contains forms *small voltaic piles*, the element consequently also performing a certain chemical work during the interruption of the current. As mentioned on p. 32, the local action can be reduced to a minimum by amalgamating the zinc. Such amalgamation is also a protection against the above-mentioned chemical work of the element, the bubbles of hydrogen adhering so firmly to the amalgamated homogeneous surface as to form a layer of gas around the zinc surface, which prevents its contact with the fluid.

Amalgamation may be effected in various ways. The zinc is either scoured with coarse sand moistened with dilute sulphuric or hydrochloric acid, or pickled in a vessel containing either of the dilute acids. The mercury may be either mixed with moist sand and a few drops of dilute sulphuric acid, and the zinc be amalgamated by applying the mixture by means of a wisp of straw or a piece of cloth; or the mercury may be applied by itself by means of a steel wire brush, the brush being dipped in the mercury, and what adheres is quickly distributed upon the zinc by brushing until the entire surface acquires a mirror-like appearance. The most convenient mode of amalgamation is to dip the zinc in a suitable solution of mercury salt and rub with a woollen rag. A suitable solution is prepared by dissolving 10 parts by weight of mercurous nitrate in 100 parts of warm water, to which pure nitric acid is added until the milky turbidity disappears. Another solution, which is also highly recommended, is obtained by dissolving 10 parts by weight of mercuric chloride (corrosive sublimate) in 12

parts of hydrochloric acid and 100 of water, or by dissolving 10 parts by weight of potassium mercuric cyanide and 2 parts potassium cyanide in 100 parts of water. In order to preserve as much as possible the coating of mercury upon the zinc, sulphuric acid saturated with neutral mercuric sulphate is used for the elements. For this purpose frequently shake the concentrated sulphuric acid (before diluting with water) with the mercury salt. As much mercuric sulphate or mercuric chloride as will lie upon the point of a knife may also be added in the elements to the zinc.

Bouant recommends instead of the addition of mercuric sulphate, to compound the dilute sulphuric acid with 2 per cent. of a solution obtained as follows: Boil a solution of  $3\frac{1}{2}$  ozs. of nitrate of mercury in 1 quart of water, with an excess of a mixture of equal parts of mercuric sulphate and mercuric chloride, and, after cooling, filter and use the clear solution.

The third reason for the decrease of the current-strength in elements with one fluid is *polarization*. By polarization is understood the appearance in the element of a second current which, being opposite to that produced by the element, weakens the action of the latter. The cause of galvanic polarization is found in the fact that the negative pole-plate becomes coated with a layer of hydrogen, from which, in consequence of the high electrolytic solution-pressure, the separated hydrogen-atoms endeavor to return to the ion-condition.

Polarization can only be entirely avoided in elements the negative pole-plate of which dips into a fluid which oxidizes the hydrogen to water, as is the case in the so-called *constant* elements with two fluids, as will be seen later on.

Proceeding from the conviction that rough surfaces allow the bubbles of hydrogen to pass off much more freely than smooth surfaces, Smee constructed the element named after him. It consists of a zinc plate and a platinized silver plate dipping into dilute acid. It may be formed of two zinc plates mounted with the platinized silver between them in a wooden frame, which being a very feeble conductor may carry away a minute fraction

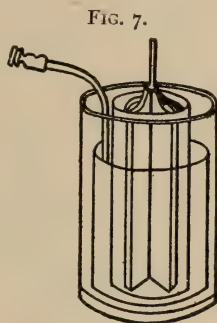
of the current, but serves to hold the metals in position, so that quite a thin sheet of silver may be employed without fear of its bending out of shape and making a short circuit. The platinizing is effected by suspending the silver plates in a vessel filled with acidulated water, adding some chloride of platinum, and placing the vessel in a porous clay cell filled with acidulated water and containing a piece of zinc, the latter being connected with the silver plates by copper wire. The platinum coating obtained in this manner is a black powder which roughens the surfaces, in consequence of which the bubbles of hydrogen become readily detached and the polarization is less than with silver plates not platinized. The use of electrolytically prepared copper plates, which are first strongly silvered and then platinized, is still more advantageous on account of their greater roughness. To increase the constancy of the element, it is advisable to add some chloride of platinum to the dilute acid of the element.

The Smee element is still frequently used in England and in the United States, especially in processes for which at first a higher current-strength is required, whilst later on a less intensity suffices, or is even necessary, as, for instance, in silvering. The electro-motive force is about 0.48 volt.

As previously mentioned, polarization can be entirely avoided only by allowing the electro-negative pole-plate to dip in a fluid which, by combustion, reduces the hydrogen evolved to water, or, in other words, which immediately oxidizes the hydrogen to water. From this conviction originated the so-called *constant elements* with two fluids, the first of these elements being, in 1829, constructed by Becquerel, which, in 1836, was succeeded by the far more effective one of Daniell.

As most generally used, Daniell's element (Fig. 7) consists of a glass vessel, a copper cylinder, a porous clay cell, and a rod of zinc suspended in the latter. The glass vessel is filled with concentrated solution and a small piece of blue vitriol, and the porous clay cell with dilute sulphuric acid. The

oxygen evolved on the electro-positive zinc oxidizes the latter, sulphate of zinc being formed, while the hydrogen separating on the electro-negative copper reduces from the blue vitriol solution a quantity of copper equivalent to it, which separates upon the electro-negative plate. However, after a comparatively short time of working, the dilute sulphuric acid is consumed for the formation of sulphate of zinc, the electro-motive force becoming very weak. The necessity of frequently renewing the dilute sulphuric acid is an inconvenience which the Daniell element shows more than any other. Furthermore, by the action of osmose, blue vitriol solution gets into the porous cell, where it is decomposed by coming in contact with the zinc, the copper being separated upon the latter, whereby the effect is destroyed or at least very much weakened. The electro-motive force of the Daniell element is about 1 volt.



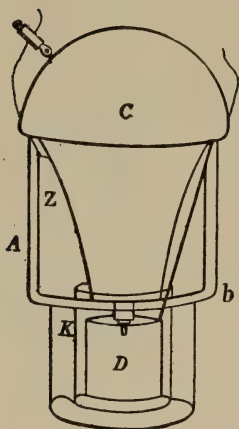
The *Meidinger element* may be considered a modified Daniell element. Like the Callaud element, it has no porous division, the mixture of the two fluids being prevented by their different specific gravities. The shape of the Meidinger element, as most generally used, is shown in Fig. 8.

Upon the bottom of a glass vessel, *A*, provided at *b* with a shoulder, stands a small glass cylinder, *K*, which contains the electro negative copper cylinder *D*; from the latter a conducting wire leads to the exterior. Upon the shoulder, at *b*, rests the zinc cylinder *Z*, which is also provided with a conducting wire leading to the exterior. The balloon *C* closes the vessel by being placed upon it. The balloon is filled with pieces of blue vitriol and Epsom salt solution. The entire element is also filled with Epsom salt solution (1 part Epsom salt to 5 water). In the balloon *C* concentrated solution of blue vitriol is formed which flows into the glass cylinder *K*. If the circuit is not closed, the concentrated copper solution remains quietly



standing in *K*, its greater specific gravity preventing it from rising higher and reaching the zinc. If, however, the circuit

FIG. 8.



be closed, zinc is dissolved, while metallic copper is separated from the blue vitriol solution, and concentrated solution flows from the balloon *C* to the same extent as the blue vitriol solution in *D* becomes dilute by the separation of copper. Hence the action of the element remains constant for quite a long time, and of all the modified forms of Daniell's element consumes the least blue vitriol for a determined quantity of current. However, in consequence of its great internal resistance (9.90 ohms) its current-strength is small. The electro-motive force of the Meidinger element is 0.95 volt.

Grove, in 1839, substituted platinum for copper. The platinum dips in concentrated nitric acid, while the zinc cylinder stands in dilute sulphuric acid. The hydrogen liberated on the platinum is oxidized to water by the nitric acid, hyponitrous acid escaping in the form of gas. The electro-motive force of the Grove element is at first double that of the Daniell element, but it soon abates on account of the dilution of the nitric acid by water. To prevent this weakening, concentrated sulphuric acid, which absorbs the water formed by the oxidation of the hydrogen, may be added to the nitric acid. Though the resistance of the Grove element is small (0.7 to 0.75 ohm), and its electro-motive force 1.70 to 1.90 volts, according to the concentration of the solutions, it is but seldom used on account of its costliness.

Bunsen, in 1841, replaced the expensive platinum by prisms cut from gas-carbon, which is still less electro-negative than platinum, and very hard and solid, so that it perfectly resists the action of the nitric acid. In place of the gas-carbon an *artificial carbon* may be prepared by kneading a mixture of

pulverized coal and coke with sugar solution or syrup, bringing the mass under pressure into suitable iron moulds and igniting it with the exclusion of air. After cooling, the carbon is again saturated with sugar solution (others use tar, or a mixture of tar and glycerine) and again ignited with the exclusion of air, these operations being, if necessary, repeated once more, especially when great demands are made on the electro motive force and solidity of the artificial carbons.

Figs. 9, 10, and 11 show the three forms of Bunsen's elements most generally used.

Fig. 9, which is the most convenient and practical form, consists of an outer vessel of glass or earthenware. In this is

FIG. 9.

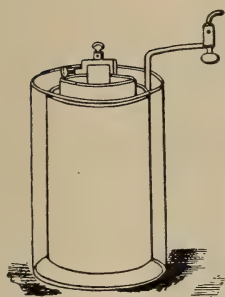


FIG. 10.

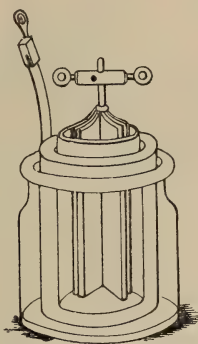
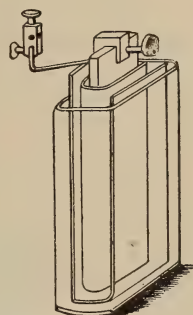


FIG. 11.

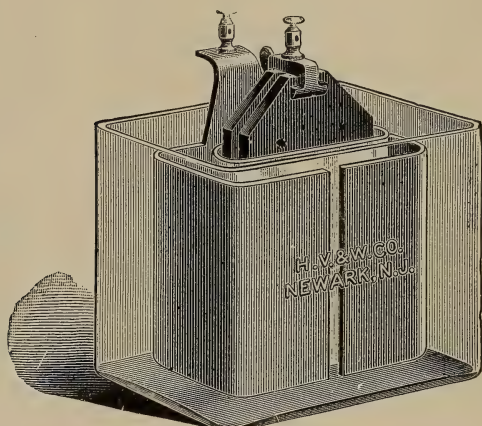


placed a cylinder of zinc in which stands a porous clay cell, and in the latter the prism of gas-carbon. This substance is the graphite of the gas retorts. It is not coke. It is easily procurable in lump at a small price, but costs much more when cut into plates, as, when the material is good, it is exceedingly difficult to work. It is generally cut with a thin strip of iron and watered silver-sand. Blocks of Bunsen cells cost less because they are more easily produced. Rods for Bunsen cells should be a few inches longer than the pots to protect the top contact from the acid. A good carbon is of a clear gray appearance, has a finely granulated surface, and is very hard. A

band of copper is soldered or secured by means of a binding-screw to the zinc cylinder, while the prism of gas-carbon carries the binding-screw (armature), as seen in Fig. 9, in the upper part of which a copper sheet or wire is fixed for the transmission of the current. The other vessel is filled with dilute sulphuric acid (1 part by weight of sulphuric acid of  $66^{\circ}$  Bé.—free from arsenic—and 15 parts by weight of water), and the porous cell with concentrated nitric acid of at least  $36^{\circ}$  Bé., or still better  $40^{\circ}$  Bé., care being had that both fluids have the same level.

In Fig. 10 the cylinder of artificial carbon is in the glass ves-

FIG. 12.



sel, while the zinc, which, in order to increase its surface, has a star-like cross-section, is placed in the porous clay cell. In this case the outer vessel is filled with concentrated nitric acid, and the clay cell with dilute sulphuric acid.

The form of the Bunsen element shown in Fig. 9 is more advantageous, because its effective zinc surface can be kept larger. Fig. 11 shows a plate element such as is chiefly used for bichromate batteries.

Fig. 12 shows an *improved* Bunsen cell of great power for nickel and electro-plating, electro-motors, etc. It has an elec-

tro-motive force of 1.8 volts. When the absence of power prevents the use of a dynamo, a battery of these elements is very suitable for nickel-plating. It is an easy battery to set up and keep in working order. The batteries are set up by well amalgamating, inside and outside, the zinc, and placing it in the jar. Inside the zinc, place the porous cup, and within the porous cup the carbon, and then pour nitric acid in the porous cup. In the outer jar pour a mixture of 1 part sulphuric acid to 12 of water (previously mixed and allowed to cool).<sup>\*</sup> This acid mixture should cover the zinc or be on a level with the liquid in the porous cup. When the liquid in the outer jar becomes milky, withdraw it with a syringe or siphon, and refill, adding occasionally small quantities of nitric acid to the porous cup, and keeping the zinc thoroughly amalgamated by one of the methods given on page 36. A very good plan of amalgamating zinc is as follows: Dip in lye to remove grease, rinse, next dip in the dilute acid in the glass jar, and then brush over with about 2 ozs. of mercury contained in a little flannel bag.

*Electro-potion* may be substituted for the nitric acid in the porous cup. This battery liquid consists of 1 lb. of bichromate of potash dissolved in 10 lbs. of water, to which  $2\frac{1}{2}$  lbs. of commercial sulphuric acid have been gradually added.

The Bunsen elements are much used for electro-deposition, since they possess a high electro-motive force (1.88 volts) and, on account of slight resistance (0.25 ohm), develop considerable current-strength. Like the Grove element, they have the inconvenience of evolving vapors of hyponitrous acid, which are not only injurious to health, but also attack the metallic articles in the workshop. Wherever possible they should be placed in a box at such a height that they may be readily manipulated. This box should have means of ventilation in such a way that the air coming in at the lower part will escape at the top through a flue, and carry away with it the acid

<sup>\*</sup> The sulphuric acid should be poured into the water; not the water into the acid.



fumes disengaged. It is still better to keep the elements in a room separate from that where the baths and metals are located. Furthermore, as the nitric acid becomes diluted by the oxidation of the hydrogen, and the sulphuric acid is consumed in the formation of sulphate of zinc, the acids have to be frequently renewed.

To avoid the acid vapors, as well as to render the elements more constant, A. Duprè has proposed the use of a 30 per cent. solution of bisulphate of potash in water in place of the dilute sulphuric acid, and a mixture of water 600 parts, concentrated sulphuric acid 400, sodium nitrate 500, and bichromate of potash 60, in place of the nitric acid.

The following method can be recommended: The outer vessel which contains the zinc cylinder is filled with a moderately concentrated (about 30 per cent.) solution of bisulphate of potash or soda, and the clay cell with solution of chromic acid—1 part chromic acid to 5 parts water. As soon as the electro-motive force of the element abates, it is strengthened by the addition of a few spoonfuls of pulverized chromic acid to the chromic acid solution. It is better to use the chromic acid in the form of powder, which is especially prepared for this purpose, than a chromic acid solution produced by mixing solution of bichromate of potash with sulphuric acid, a disturbing effect being exerted by the tendency of such a solution to form crystals.

The chromic acid solution loses effect in a comparatively short time, the electro-motive force decreasing in a few hours, and chromic acid must be added, or the element refilled.

Another soluble chromium combination which depolarizes with rapidity and maintains the constancy of the elements for a much longer time, is obtained by treating pulverized chrome-ironstone with concentrated sulphuric acid and carefully diluting with water. With a single filling of this solution the battery may be kept working for six days from morning to evening without refilling being required. During the nights the battery remains filled but inactive. The electro motive

force of an element filled with this solution is 1.8 volts. On account of its lasting quality and great constancy, and consequent cheapness, this filling would appear to be the most suitable.

In using nitric acid it is also advantageous to pour a 0.39 to 0.78 inch thick layer of oil upon the acid, to decrease the vapors.

The binding-screws which effect the metallic contacts must of course be frequently inspected and cleaned, which is best done by means of a file or emery paper. It is advisable to place a piece of platinum sheet between the binding surface of the carbon armature and the carbon in order to prevent the acid rising through the capillarity of the carbon from acting directly upon the armature (generally brass or copper). To prevent the acid from rising, the upper portions of the carbons may be impregnated with paraffine. For this purpose the carbons are placed  $\frac{3}{4}$  to 1 inch deep in melted paraffine and allowed to remain 10 minutes. On the sides where the armature comes in contact with the carbon, an excess of paraffine is removed by scraping with a knife-blade or rasp.

*Manipulation of Bunsen elements.*—Before using the elements the zinc cylinders should be very carefully amalgamated according to one of the methods given on p. 36. The nitric acid need not be pure, the crude commercial acid sufficing, but it should be as concentrated as possible and show at least 36° Bé. For the prisms it is best to take carbon produced in gas houses using coal without the addition of lignite or brown coal, the electro-motive force of the latter being less. If artificial carbon is employed, it should be examined as to its suitability, the non-success of the plating process being frequently attributed to the composition of the bath, when in fact it is due to the defective carbons of the elements. In order to avoid an unnecessary consumption of zinc and acid, the elements are taken apart when not in use, for instance, over night. Detach the brass armature of the carbon prism and lay it in water to which some chalk has been added. Lift the carbon from the clay cylinder

and place it in a porcelain dish or earthenware pot; empty the nitric acid of the clay cell into a bottle provided with a glass stopper; place the clay cell in a vessel of water, and finally take the zinc cylinder from the dilute sulphuric acid and place it upon two sticks of wood laid across the glass vessel to drain off. In putting the elements together the reverse order is followed, the zinc being first placed in the glass vessel and then the carbon in the porous clay cell. The latter is then filled about three-quarters full with used nitric acid, and fresh acid is added until the fluid in the clay vessel stands at a level with that in the outer vessel. The cleansed brass armature is then screwed upon the carbon prism. Finally, add to the dilute sulphuric acid in the outer vessel a small quantity of concentrated sulphuric acid saturated with mercury salt.

It is advisable to have at least a duplicate set of porous clay cells, and in putting the elements together to use only cells which have been thoroughly soaked in water. The reason for this is as follows: The nitric acid fills the pores of the cell, and, finally reaching the zinc of the outer vessel, causes strong local action and a correspondingly rapid destruction of the zinc. It is, therefore, best to change the clay cells every day, allowing those which have been in use to lie in water the next day with frequent renewal of the water. For the same reason the nitric acid in the clay cell should not be at a higher level than the sulphuric acid in the outer vessel.

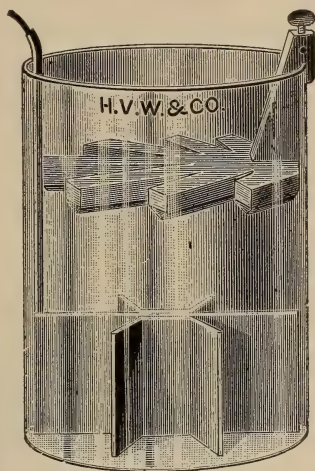
When the Bunsen elements are in steady use from morning till night, the acids will have to be entirely renewed every third or fourth day. The solution of sulphate of zinc in the outer vessel being of no value is thrown away, while the acid of the clay cells may be mixed with an equal volume of concentrated sulphuric acid, and this mixture can be used as a preliminary pickle for brass and other copper alloys.

*Foote's pinnacle gravity battery.* Gravity batteries are especially suited for continuous work at a *low* rate, the operating cost being as low as, if not lower than, any other type of battery. Four of these cells in series will charge a small storage

battery. The type of gravity shown in Fig. 13 is one of the best in the market.

The battery is set up by placing the copper cross and zinc in position. Pour clean water into the jar until within two inches of the top, then drop in blue vitriol (sulphate of copper) in small lumps. The battery may be made immediately available by adding 4 ozs. of pulverized sulphate of zinc. When the hydrometer reads less than  $15^{\circ}$  Bé., there is too much.

FIG. 13.



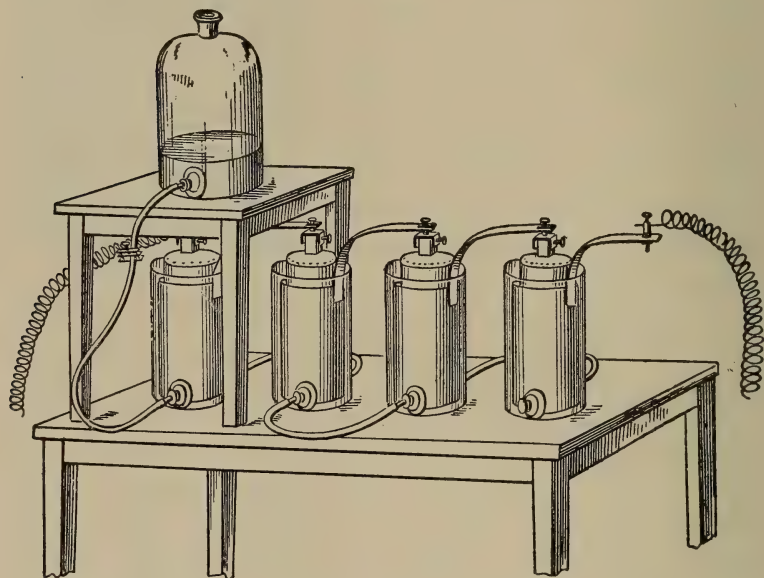
*Oppermann's element* is in the main a Bunsen element quite free from odor, but is distinguished from the latter by a hollow porcelain body which is placed upon the clay cell and filled with potassium permanganate solution whereby the escaping vapors are mostly rendered innocuous. Besides, the element when at rest consumes no materials. To avoid the inconvenience of emptying the elements, the battery jars are provided, close above the bottoms, with two tubulures opposite to one another. This arrangement allows of all the jars of a battery being connected by means of glass tubes and rubber hose as shown in Fig. 14. The first jar of the battery is connected by means of a rubber hose of suitable length with a large tubulated supply-jar, while one of the tubulures of the last jar is provided with a massive rubber stopper. The supply-jar contains the exciting fluid for the outer cells.

The clay cell of the Oppermann element is closed by a hollow porcelain lid. The latter contains a fluid capable of absorbing or decomposing the vapors evolved by the decomposition of the depolarizing fluid containing nitric acid. In the centre of the porcelain lid is a square hole in which the carbon prism is secured. The fluid in the lid consists of a solution of



potassium permanganate acidulated with a small quantity of sulphuric acid. The solution is prepared as follows: Dissolve 1 part by weight of pure potassium permanganate in 20 parts by weight of distilled water, and add to the solution about 1 part by weight of dilute sulphuric acid. The vapors of hyponitrous acid are absorbed with avidity by this solution, and oxidized partly to nitrous acid and partly to nitric acid. Both of these acids combine with the potassium or the manganous oxide, and the potassium permanganate solution, which

FIG. 14.



exhibits at first a deep violet color, is finally completely decolorized. When this is the case, which will be in about 3 or 4 hours, the solution has to be renewed. This is done in the simplest manner by introducing about 5 ccm. of the solution into the lid by means of a pipette, whereby the solution consumed is forced from the lid, passes into the clay cell and enriches the depolarizing fluid by the addition of fresh nitric or nitrous acid.

The arrangement of the elements and their combination to a battery is effected as follows: The battery jars are placed as indicated in the illustration and connected with one another by means of rubber stoppers, glass tubes bent at a right angle and short pieces of rubber hose. It is advisable first to dip the rubber stoppers in water, then to press them firmly into the tubulures, and finally to insert the glass tubes also previously moistened with water. For the sake of security the rubber stoppers are fastened to the tubulus with cord or wire. One tubulus each of the two end jars, however, remains free. The free tubulus of the last jar is tightly closed with a massive rubber stopper, while that of the first jar is provided with a perforated stopper and a glass tube, and is connected with the supply-jar by means of a rubber hose of suitable length.

In the battery-jars thus connected the zinc cylinders are first placed, and next in the latter the clay cells, and finally in the clay cells the carbon prisms. The clay cells are then filled with nitric acid of  $40^{\circ}$  Bé. The porcelain lids are next placed upon the carbon prisms and the brass binding-screws secured to the prisms. The size of the porcelain lids must be such that they reach into the clay cells and are about even with the upper edge of the latter. The holes on the upper side of the porcelain lids remain open. For filling the lids with potassium permanganate solution a pipette is used. At 5 ccm. the pipette is provided with a mark, and it is filled up to that point by dipping it in the fluid or by suction. The upper opening is then closed with the index finger of the right hand and the point of the pipette introduced into the hole of the lid. By now removing the finger the contents of the pipette run into the lid.

For filling the outer cells it is best to use a concentrated solution of common salt, which is prepared by dissolving 35 parts by weight of common salt in 100 parts by weight of water. Should the solution be very turbid, it has to be filtered. This is also necessary in case the solution, while in use, deposits a muddy sediment. In place of common salt solution, a concentrated sal ammoniac solution may be used. It is prepared by

dissolving 25 parts by weight of sal ammoniac in 75 parts by weight of water. Dilute sulphuric acid (1 part by weight of pure sulphuric acid in 30 parts by weight of water), with an addition of a small quantity of neutral sulphate of mercury, is also suitable as an exciting fluid. Common salt solution, however, deserves preference; and its action can be strengthened by the addition of a very small quantity of dilute sulphuric acid. The exciting fluid is brought into the supply-jar. The ordinary element is 7.87 inches in height and, when this size is used, the supply-jar must have a capacity of at least as many quarts as there are elements in the battery. To fill the jars the supply-jar is placed at a higher level and the cock opened. The solution then runs into all the battery-jars connected with one another. After connecting the copper band of the zinc cylinder with the binding-screw of the carbon of the next element, the battery is ready for use. To connect the end poles of the battery with the respective apparatus, quite stout copper wire thoroughly insulated should be used. The wire should be 0.079 inch in diameter, and be as short as possible.

When work with the battery is to be interrupted, the supply-jar is placed at a lower level and the cock opened. The exciting fluid then escapes from the outer cells of the elements, and the development of current ceases. While the battery is not in use, a small portion of the depolarizing fluid oozes through the clay cells and collects upon the bottom of the battery-jars. This fluid must be removed before the battery is again put in operation. For this purpose the glass tubes bent at a right angle inserted in the tubulures of the jars are turned so that one leg points upwards. The rubber hoses are then withdrawn, the bent glass tubes turned downward and the jars emptied by tilting them. For filling the clay cells with fresh nitric acid, a glass funnel with glass cock and long discharge tube is used, whereby it is, however, necessary to slightly lift the porcelain lid in order to reach the interior of the clay cell. The clay cells require emptying entirely only when the battery is not to be used for some time or when it is to be cleaned,

which has to be done once in a while. When the exciting fluid in the outer cells has become ineffective, it has to be replaced by a fresh supply. How often the battery has to be cleansed and how often the exciting fluid has to be renewed, depends of course on the length of time the battery is in use.

The efficacy of the battery can be still further increased by keeping the exciting fluid in the exterior cells in constant circulation, which is effected as follows: Each of the two end cells of the battery is connected with a supply-jar of suitable capacity and the full jar of the two supply-jars is placed at a higher, and the empty jar at a lower, level. By means of a screw-clip the discharge and influx of the fluid are so regulated that the latter always stands at the same, level. When the upper jar is empty, the position of the jars is reversed. By now placing the two supply-jars in a tub containing ice and thus constantly cooling the circulating exciting fluid, the heating of the elements which otherwise constantly takes place is avoided, and the battery can be kept working for a longer time without interruption.

The ordinary Oppermann element, which is 7.87 inches high, has an electro-motive force of 1.85 to nearly 1.9 volts. The current strength measured on the open element by means of the spiral ammeter is 15 to 20 amperes. The quantity of oxy-hydrogen gas evolved, measured by the voltmeter, amounts to about 20 ccm. per minute.

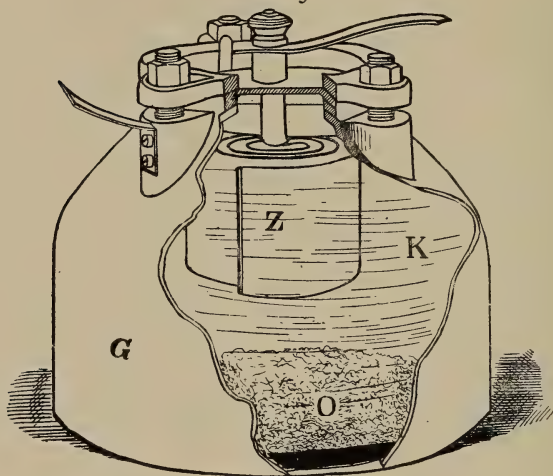
The *Leclanché* element (zinc and carbon in sal ammoniac solution with manganese peroxide as a depolarizer) need not be further described, it not being adapted for regular use in electro-plating. It is in very general use for electric bells, its great recommendation being that, when once charged, it retains its power without attention for several years.

Lallande and Chaperon have introduced a copper oxide element, shown in Fig. 15, which possesses several advantages. It consists of the outer vessel *G*, of cast-iron or copper, which forms the negative pole surface, and to which the wire leading to the anodes is attached, and a strip of zinc, *Z*,



coiled in the form of a spiral, which is suspended from an ebonite cover carrying a terminal connected with the zinc. The hermetical closing of the vessel *G* by the ebonite cover is effected by means of three screws and an intermediate rubber plate. Upon the bottom of the vessel *G* is placed a 3 to 4 inch deep layer of copper oxide, *O*, and the vessel is filled with a solution of 50 parts of caustic potash in 100 of water. When the element is closed, decomposition of water takes place, the oxygen which appears on the zinc forming with the latter zinc oxide, which readily dissolves in the caustic potash solution,

FIG. 15.



while the hydrogen is oxidized with the simultaneous reduction of copper oxide to copper. When the element is open, *i. e.*, the circuit not closed, neither the zinc nor the copper oxide is attacked, and hence no local action nor any consumption of material takes place. The electro-motive force of this element is 0.98 volt, and its internal resistance very low. It is remarkably constant, and is well adapted for electro-plating purposes by using two of them for one Bunsen element. The following rules have to be observed in its use. It is absolutely necessary that the ebonite cover should hermetically close the vessel *G*, as

otherwise the caustic potash solution would absorb carbonic acid from the air, whereby carbonate of potash would be formed, which would weaken the exciting action of the solution. Further, the vessels *G* which form one of the poles must be insulated one from the other as well as from the ground, as otherwise a loss of current or defective working would be the consequence.

The regeneration of the cuprous oxide or metallic copper formed by reduction from the cupric oxide to cuprous oxide, requires it to be subjected to calcination in a special furnace. The expense connected with this operation is, however, about the same as that of procuring a fresh supply of cupric oxide. Lallande himself, as well as Edison, endeavored to bring the pulverulent cupric oxide into compact plates, but the regeneration of these plates was still more troublesome. By treatment with various chemical agents, Dr. Böttcher, of Leipsic, has succeeded in producing porous plates of cupric oxide which, after subsequent reduction by absorption of oxygen from the air, can be readily re-oxidized to cupric oxide, but as far as we know, elements with these plates have not yet been introduced into commerce.

Umbreit & Matthes bring into commerce an element known as *cupron element*, which is an improved Lallande element, and in which the cupric oxide is also brought into the form of plates. A square glass vessel or vat with a ground edge and closed with a hard-rubber lid contains two zinc plates, and between the latter the porous cupric oxide plate. The glass vessel is filled with 20 per cent. caustic soda lye, and the current is delivered through two clamps on the outside of the lid. According to Umbreit and Matthes' statements the reduced positive pole plates are regenerated, that is, re-oxidized to cuprous oxide by rinsing in water and allowing them to remain in a warm place for 20 to 24 hours, so that it is only necessary to replace the soda lye saturated with zinc oxide. The electro-motive force of the element is 0.8 volt; the normal current-strength, according to the size of the elements 1, 2, 4

and 8 ampères. Like the Lallande element, this element works without odor. An addition of sodium hyposulphite to the soda lye is claimed to produce uniform wear and greater durability of the zinc plates.

The elements of Mariè, Davy, Niaudet, Duchemin, Sturgeon, Trouville, and others, being of little practical value, may be passed over.

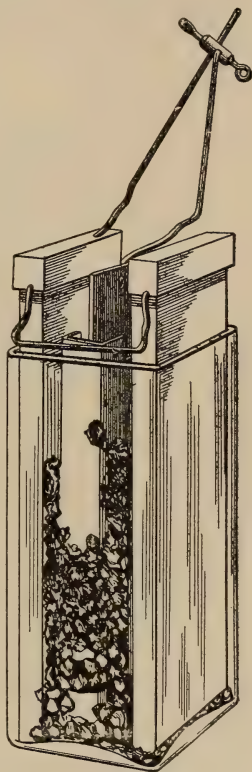
*Dun's potash element.* On account of its great electromotive force (1.6 volts) and slight internal resistance, this element would be well adapted for electro-plating purposes, if depolarization were effected more rapidly than is actually the case. Its construction is as follows: In a glass vessel stands a hollow coke cylinder fitted with a bottom, and in the centre of the coke cylinder a clay cell. The space between the clay cell and the interior wall of the coke cylinder is filled five-sixths full with pieces of coke. In the clay cell stands an amalgamated strip of zinc or zinc cylinder to which the conducting wires are soldered, the place of soldering, as well as the wire as far as it comes in contact with the fluid, being covered with gutta-percha. The edge of the coke cylinder is coated with paraffine and carries the pole binding-screw. The filling of the element is effected by laying potassium permanganate in crystals upon the layer of carbon between the clay and coke cylinders, and pouring a solution of 1 part of pure caustic potash in 2 of water into the clay cell, the pouring being continued until the fluid runs over the clay cell upon the potassium permanganate and the layer of coke, and finally fills the outer vessel up to about the breadth of two fingers from the edge. The action of the element is as follows: When the element is closed decomposition of water takes place, the oxygen combining with the zinc to form zinc oxide, which is dissolved by the potash lye, while the hydrogen is oxidized on the positive pole by the potassium permanganate. The latter, to be sure, contains much oxygen, and acts very energetically, but as it diffuses very slowly, depolarization, *i. e.*, the removal of the hydrogen, is not so rapidly effected as, for instance, in the

Bunsen element, where the nitric acid rapidly diffuses. Hence with a slight external resistance, for instance, baths where the element has to furnish large quantities of current, the electro-motive force sinks very rapidly and with it the current strength, and, therefore, the element is only suitable for electro-plating purposes when a current is only required for a short time, but not for permanent work. In the first case it offers the advantage of being always ready for use, evolving no vapors, and when not in use consuming no material. It is prudent to protect this element from the action of the carbonic acid of the air by a close cover.

The element shown in Fig. 16 has been patented in Germany, and is described by Knaffe and Kiefer,\* of Vienna, as follows: The element consists of a combination of zinc and carbon. The zinc plate is  $9\frac{1}{2}$  inches long,  $4\frac{3}{4}$  inches wide, and of the thickness of pasteboard. It is amalgamated according to a new process. It is placed between two carbon plates of equal size, the surface of which is twice that of the zinc. The carbon plates are connected with the conducting wires in such a manner as to prevent oxidation of the binding-screws and to secure constant contact. The zinc plate is suspended in a neutral salt solution in a clay cell, the space between the latter and the carbon plates being filled with pieces of coke. The consumption of zinc is very small. The principal advantage of this new element is, however, the depolarizing fluid of peculiar composition and powerful effect.

The element has an electro-motive force of 1.9 volts, an in-

FIG. 16.



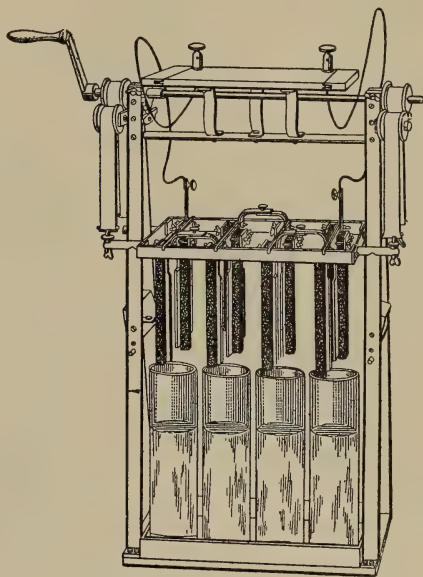
\* *Neueste Erfindungen und Erfahrungen*, vol. xviii, p. 308.



ternal resistance of 0.17 ohm, and a constancy such as seldom is attained with primary elements, 1 volt ampère lasting for 100 hours.

A few words may be added in regard to *plunge* or *bichromate* batteries, which may be constructed for the different kinds of elements. For our purpose it will suffice to mention the *Bunsen plunge battery*, shown in Fig. 17. For constructive reasons only one fluid is used, into which the zinc as well as

FIG 17.



the carbon plates dip, a solution of chromic acid prepared by dissolving 10 parts of bichromate of potash and  $\frac{1}{2}$  part of mercuric sulphate in 100 parts of water, and adding 18 parts of pure concentrated sulphuric acid, being employed. More advantageous is a solution of chromic acid in the form of powder in water, in the proportion of 1 : 5, for the same reason as given on p. 44.

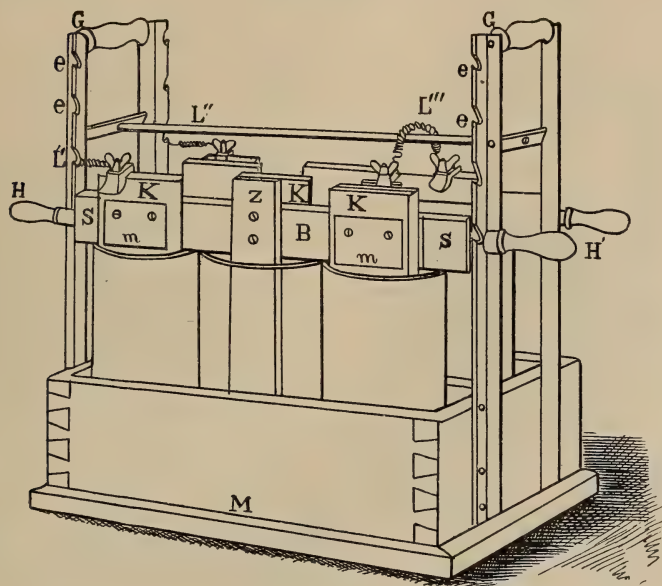
Fig. 18 shows a bichromate battery as constructed by Fein. Into the 6 element vessels standing in two rows in the wooden

box *M* dip the zinc and carbon plates, which are secured to wooden cross-pieces provided with handles, and may be maintained at any desired height by the notches *e* in the standard *G*. According to the current-strength required, the plates are allowed to dip in more or less deeply.

Fig. 19 shows a bichromate battery as constructed by Keiser & Schmidt.

In using the above-mentioned chromic acid solution first

FIG. 18.



recommended by Bunsen, the elements first developed a very strong current, which, however, in a comparatively short time becomes weaker and weaker. The current-strength can be increased by adding at intervals a few spoonfuls of pulverized chromic acid to the chromic acid solution, which, however, finally remains without effect, when the battery has to be freshly filled. Hence, these batteries are not suitable for electroplating operations requiring a constant current for some time.

For temporary use, for instance by gold-workers and others, for gilding or silvering small articles, the bottle-form of the bichromate element (Fig. 20) may be advantageously employed. In the bottle *A* two long strips of carbon united above by a metallic connection are fastened parallel to one another to a vulcanite stopper, and are there connected with the binding-screw; these form the negative element, and pass to the bottom of the bottle. Between them is a short thick strip of zinc attached to a brass rod passing stiffly through the centre of the vulcanite cork, and connected with the binding-screw.

FIG. 19.

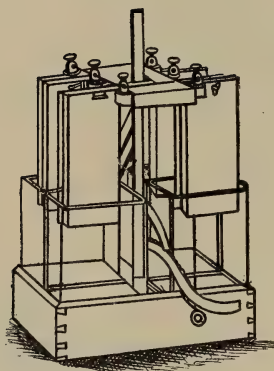
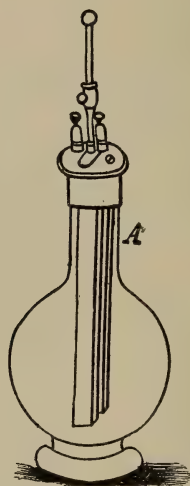


FIG. 20.



The zinc is entirely insulated from the carbon by the vulcanite, and may be drawn out of the solution by means of the brass rod as soon as the services of the element are no longer required.

This bichromate element is excellent for purposes requiring strong currents, where long action is not necessary. As this element readily polarizes, it cannot be advantageously employed continuously for any considerable period of time. It becomes depolarized, however, when left for some time on open circuit. The element gives an electro-motive force of about 1.9 volts.

In Stoecher's element (Fig. 21) two acids, dilute sulphuric acid and concentrated nitric acid, are used. The porous clay cell is omitted, the massive carbon cylinders *K*, *K*, etc., being provided with a cavity reaching almost to the bottom, which is filled with sand and nitric acid. The contact of the carbon and zinc cylinders is prevented by glass beads imbedded in the carbon cylinders.

FIG. 21.

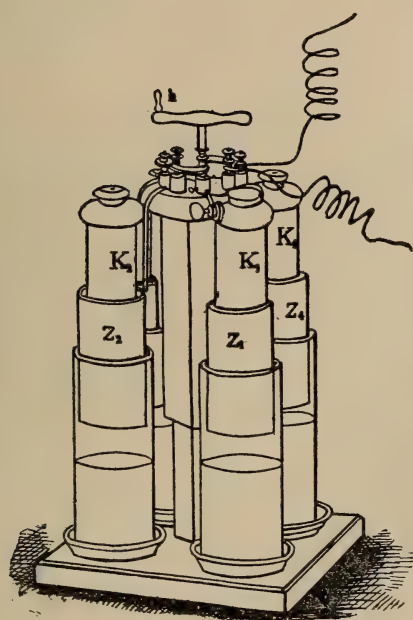


FIG. 22.

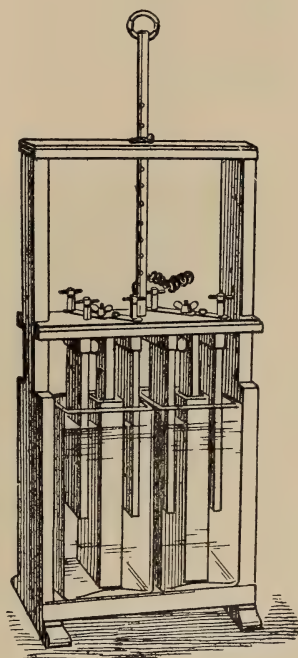


Fig. 22 shows a plunge element manufactured by Dr. G. Langbein & Co., at Leipzig-Sellerhausen, Germany, the details of which will readily be understood without further description. The zinc plates dip into the diaphragms, which are filled with a mixture of 26 lbs. of water and 2 lbs. of sulphuric acid free from arsenic in which  $2\frac{3}{4}$  ozs. of amalgamating salt have previously been dissolved. The carbon plates dip into the glass vessels, which contain a solution of commercial crystallized



chromic acid in water in the proportion of 1 part acid to 9 water. In place of this pure chromic acid solution the following mixture may also be used :

Water 10 parts by weight, sodium dichromate 1.5 parts by weight, pure sulphuric acid of  $66^{\circ}$  Bé. 3 parts by weight.

This solution shows no inclination towards crystallization. In the illustration only two elements are combined to a battery, but in the same manner a plunge battery of four or eight elements may be constructed, the separate elements of which may all be coupled parallel, as well as one after the other, and in mixed groups.

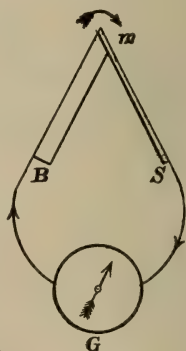
#### B. THERMO-ELECTRIC PILES.

Though thermo-electric piles are only used in isolated cases for electro-plating operations, for the sake of completeness their nature and best-known forms will be briefly mentioned.

In the year 1822, Professor Seebeck, of Berlin, discovered a new source of electricity, namely, inequality of temperature and conducting power in different metals, or in the same metal in different states of compression and density. When two pieces of different metals, connected together at each end, have one of their joints more heated than the other, an electric current is immediately set up. Of all the metals tried, bismuth and antimony form the most powerful combination.

In Fig. 23  $Bm$  represents a bar of bismuth, and  $mS$  a bar of antimony soldered to the bismuth bar. By leading wires from  $B$  and  $S$  to a galvanoscope,  $G$ , and heating the point of junction  $m$ , the needle of the galvanoscope is deflected. From this it may be concluded that an electric current circulates in the closed circuit  $GB mSG$ . By a closer examination the direction of the current may be recognized, it flowing on the heated point of junction from the bismuth to the antimony, and in the connecting wire of the ends

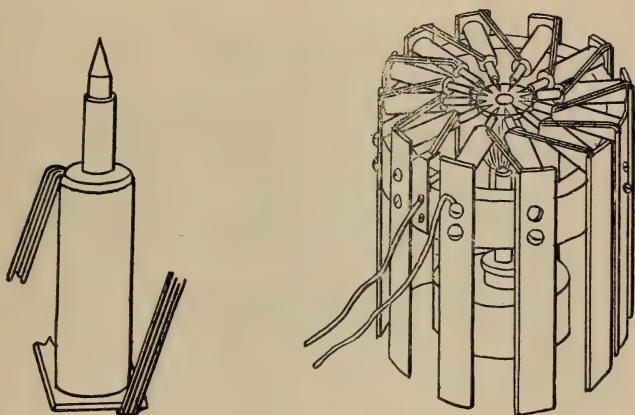
FIG. 23.



of the rods which remain cold, from the antimony to the bismuth. The current is the stronger the greater the difference in the temperature of the point of junction and the free ends of the bars. Hence the electric current will be especially strong when the place of junction is heated and the ends *B* and *S* are at the same time cooled off. A combination as above described is called a *thermo-electric couple*, and the electricity obtained in this manner *thermo-electricity*. By a suitable combination of several or many of such couples, a thermo-electric pile is obtained.

*Noe's thermo-electric pile* (Fig. 24) consists of a series of

FIG. 24.

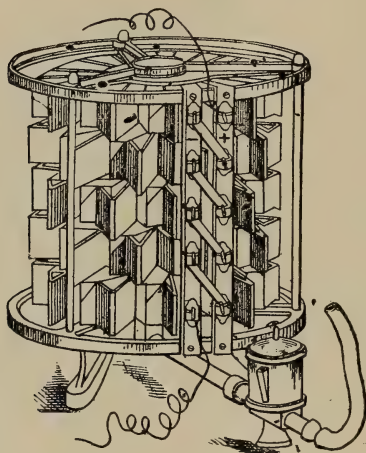


small cylinders, composed of an alloy of  $36\frac{1}{2}$  parts of zinc and  $62\frac{1}{2}$  parts of antimony for the positive element, and stout German silver as the negative element. The junctions of the elements are heated by small gas-jets, and the alternate junctions are cooled by the heat being conducted away by large blackened sheets of thin copper. A pile of twenty pairs has an electro-motive force of 1.9 volts.

*Clamond's thermo-electric pile* (Fig. 25) consists of an alloy of 2 parts antimony and 1 of zinc for the negative metal, while for the positive element ordinarily tinned sheet-iron is employed, the current flowing through the hot junction from the

iron to the alloy. To insure a good contact between the two metals a strip of tin-plate is bent into a narrow loop at one end. This portion is then placed in a mould and the melted alloy poured around it, so that it is actually imbedded in the casting. The pile shown in the illustration consists of five series, one placed above the other. Each series has ten elements grouped in a circle, and is insulated from the succeeding series by a layer of cement, composed of powdered asbestos moistened with a solution of potassium silicate. With the consumption of about  $6\frac{1}{2}$  cubic feet of gas per hour, such a pile precipi-

FIG. 25.

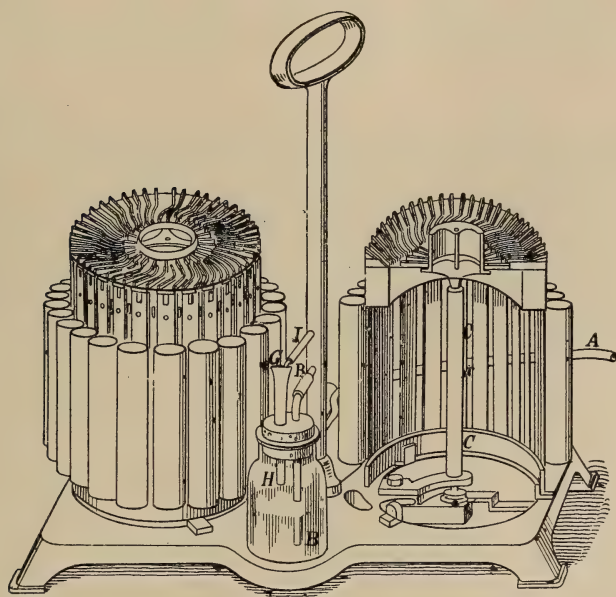


tates 0.7 oz. of copper, which corresponds to an electro-motive force of about 17 ampères.

*Hauck's thermo-electric pile.*—An essential defect of Clamond's thermo-electric pile consists in that the junctions of the dissimilar metals are subjected to ready destruction by being exposed to the direct action of the flame. Further, it is very difficult, or at least inconvenient, to make repairs, since in such a case it may become necessary to take the entire pile apart. Hauck has successfully overcome these defects by adopting the principle of indirect heating, as well as by giving the couples a more

suitable form and by improving the alloy. The couples form four-sided wedges, to which are attached cast-iron pieces that transfer the heat of the gas-burner to the couples. The electromotive force of a single couple is  $\frac{1}{10}$  that of a Daniell element. Fig. 26 shows a combination of two piles standing upon a common plate, one of the piles being given in cross-section. The glass-vessel *H*, with the tube, *B*, *G*, *R*, *I*, serves as a regulator for the gas-pressure. The pile shown in the illustration serves

FIG. 26.



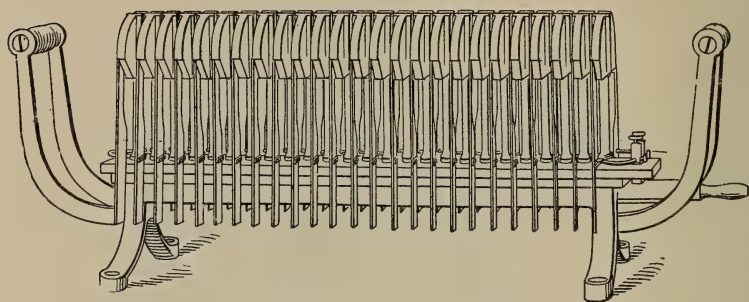
for the production of metallic deposits on a small scale, especially for analytical examinations. Hauck, however, also furnishes combinations of three larger piles.

*Gülcher's thermo-electric pile*, invented in 1890, is shown in Fig. 27. It is arranged for gas-heating, and with a constant supply of gas requires a pressure-regulator. The negative electrodes consist of nickel and the positive electrodes of an antimony alloy, the composition of which is kept secret. The



negative nickel electrodes have the form of thin tubes and are secured in two rows in a slate plate, which forms the termination of a gas conduit with a U shaped cross-section beneath it. Corresponding openings in the slate plate connect the nickel tubes with the gas conduit, the latter being connected by means of a rubber tube with the pipe supplying the gas. Thus the gas first passes into the conduits, next into the nickel tubes, and leaves the latter through six small holes in a soap-stone socket screwed in the end of each tube. On leaving these sockets the gas is ignited and the small blue flames heat the connecting piece of the two electrodes. This connecting piece consists of

FIG. 27.



a circular brass plate placed directly over the soap-stone socket. One end of it is soldered to the nickel tube, while the other ends, towards the top, in a socket in which are cast the positive electrodes. The latter have the form of cylindrical rods with lateral angular prolongations. To the ends of these prolongations are soldered long copper strips secured in notches in the slate plate. They serve partially for cooling off and partially for connecting the couples. For the latter purpose each copper strip is connected by a short wire with the lower end of the nickel tube belonging to the next couple. When the pile is to be used, the gas is ignited in one place, the ignition spreading rapidly through the entire series of couples. In about 10 minutes the junctions of the metals have attained their highest

temperature and the pile its greatest power, which, with a constant supply of gas, remains unchanged for days or weeks.

In view of the conversion of the heat produced by the combustion of the gas into electricity, the useful effect of the thermo-electric pile can be considered only a very slight one. One cubic meter of ordinary coal-gas produces on an average 5200 heat-units, hence 200 litres per hour referred to one second  $\frac{1}{5} \cdot \frac{1}{60} \cdot \frac{1}{60}$ .  $5200 = 0.29$  heat-unit. These correspond to 1208 volt-ampères, 1 volt-ampère being equal to 0.00024 heat-unit. Hence, in Gülcher's thermo-electric pile, which of all known thermo-piles produces the greatest useful effect, not much more than 1 per cent. of heat is utilized in the entire circuit, and about  $\frac{1}{2}$  per cent. in the outer circuit.

Although thermo-electric piles may be, and are occasionally, used for electro-plating operations, they cannot compete with dynamo-electric machines driven by steam, which as regards the consumption of heat are at least five times more effective. They can only be used in place of galvanic batteries, they having the advantage of being more convenient to put in operation, more simple, cleanly, odorless, and requiring less time for attendance. But, on the other hand, their original cost is comparatively large, it being ten to twenty times that of Bunsen elements. Thus, for instance, Gülcher's thermo-electric pile costs \$37.50 in Germany, to which have to be added \$5 for the gas-pressure regulator, if required.

#### C. MAGNETO- AND DYNAMO-ELECTRIC MACHINES.

It is a well-known fact that all the early experiments and improvements in dynamos were made with a view of perfecting an electrical machine for plating, and that the success attained therein was the forerunner of all the magnificent dynamo machines for other purposes in such general use.

The principle of induction upon which the dynamo-electric machines are based has been explained on p. 23. Faraday, in 1831, made the important discovery that by moving a coil of wire in the presence of a magnet a current of electricity was

generated in the coil, or, *vice versa*, by moving the magnet and holding the coil stationary a like result was obtained. Thus a current of electricity was produced either by moving a wire in the presence of a stationary magnet, or by moving a magnet in the presence of a stationary wire.

The intensity of the current thus obtained depends on the power of the magnet and on the velocity with which the magnet or coil is moved through the magnetic field. Upon these simple facts is based the whole of the recent important developments of electrical science.

Before describing the various attempts made to devise some mechanical means whereby the different elements which produced the temporary or momentary currents could be combined, so as to collect them, and cause them to flow in rapid succession, the one after the other, without interruption, it will be well to remember that the necessary elements for producing these induced electric currents are simply a bar magnet and an insulated coil of wire. It will also be well to remember that every magnet, no matter what its form, has two poles—a north and a south pole—and each of these poles exerts a certain influence in its immediate neighborhood, the space thus affected being termed the *magnetic field* or the *region of the lines of force*. The attraction or magnetic force of these lines varies as the inverse ratio of the square of the distance; therefore, the nearer the magnet the greater the intensity of the magnetism. Faraday proved that these lines, which he designated *lines of force*, showed by their position the direction of the magnetic force, and by their number its intensity. By passing a coil of wire through this field, so as to cause it to cut, as it were, a number of these lines of force, a current of electricity will be generated in the coil; and if it can be so arranged that a number of these coils will pass in rapid succession through the magnetic field, we shall have a series of impulses giving us practically a continuous stream of electricity.

Thus a magneto-electric or dynamo-electric machine is simply a machine for the conversion of mechanical energy into

electrical energy by means of magneto-electric induction. The term dynamo-electric machine is also applied to a machine by means of which electrical energy is converted into mechanical energy by means of magneto-electric induction. Machines of the latter class are generally called *motors*, those of the former *generators*.

Prof. S. P. Thompson defines a dynamo-electric machine as follows:—

“A machine for converting energy in the form of mechanical power into energy in the form of electric currents, or, *vice versa*, by the operation of setting conductors (usually in the form of coils of copper wire) to rotate in a magnetic field, or by varying a magnetic field in the presence of conductors.”

The term dynamo was first applied to such machines because of the form in which this machine first appeared, viz., the series-wound machine. It was self-acting, or required no excitement other than what it received by the rotation of its armature in the field of its magnets, or, indeed, in the field of the earth.

A dynamo-generator, or a dynamo-electric machine proper, consists of the following parts:—

1. The revolving portion, usually the *armature*, in which the electro-motive force is developed which produces the current.
2. The *field magnets*, which produce the field in which the armature revolves.
3. The *pole pieces*, or free terminals of the field magnets.
4. The *commutator*, by which the currents developed in the armature are caused to flow in one and the same direction. In alternating machines and in some continuous current dynamos this part is called the *collector*, and does not rectify the currents.
5. The *collecting brushes*, that rest on the *commutator cylinder*, and take off the current generated in the armature.

The number of such dynamo machines is legion. In each case the arrangement of the armature of the magnets and of the commutators is varied, but the principle is always the same—coils of insulated wire being caused to cut through magnetic fields, as already explained.



The first attempt to devise an electrical machine was made by Pixii, who, in 1832, constructed a machine consisting of a permanent magnet, which he caused to revolve in front of the iron cores of a pair of bobbins, forming an electro-magnet. This invention was improved by other workers in the field of science, especially by Saxton and Clarke, both of whom succeeded in producing very useful electric generators, in which the mechanical arrangement is the reverse of that in Pixii's—*i. e.*, the magnets are fixed and the coils of wire movable. And it is on this plan that all the subsequent machines have been constructed, as affording better results than where the coils are stationary and the magnets movable.

A great improvement was made in 1857, by Dr. W. Siemens, of Berlin. It consisted essentially in a new form of armature, which, owing to its simplicity and cheapness, is still used for many purposes, especially for electro-plating and laboratory work. It is composed of a cylinder of iron in which deep longitudinal grooves are cut resembling in section the letter H. In these grooves is wound lengthwise a single coil of wire, the two ends of which being joined to a split tube of copper on the axle form the commutator, from which the current is taken off by brushes or springs rubbing against it. By this longitudinal armature the advantage is gained of cutting the greatest number of lines of force when rotated between the poles of a series of adjacent magnets.

One of the most important inventions for the construction of electrical machines is the *ring armature* by Pacinotti (1860). With the use of this ring armature continuous currents of the same direction can be produced without the assistance of a commutator.

Next in order comes the important discovery made simultaneously, but independently, by Dr. W. Siemens and Sir C. Wheatstone—a discovery which marks the transition of the *magneto-electric* machine to that type most in use at present—the *dynamo* machine, called for convenience the *dynamo*. What Siemens and Wheatstone discovered was this: That a

current of electricity could be generated in the coils of the armature by the feeble residual magnetism in the iron cores of the electro-magnets, and that by passing this feeble current round the magnets their magnetism would be strengthened, which in turn would produce a stronger current in the armature, and this current would again react on the magnets, rendering them more powerful, this action going on until the limit of saturation is attained. For it must be understood that this mutual accumulation cannot go on indefinitely, the magnetism in the iron cores cannot be intensified beyond a certain point, and this point depends on, and is controlled, by the scientific conditions on which the machine is constructed.

Machines constructed on this principle are called, as stated, dynamo machines, to distinguish them from those previously used in which the magnets were permanently magnetized, thus causing the division of electric generators into two great classes, viz., *magneto* and *dynamo* machines, which are subdivided into two varieties—one called the *continuous* current machine, furnishing currents in the same direction, and the other the *alternating* current machine, wherein the current is rapidly reversed or its direction changed many times a minute.

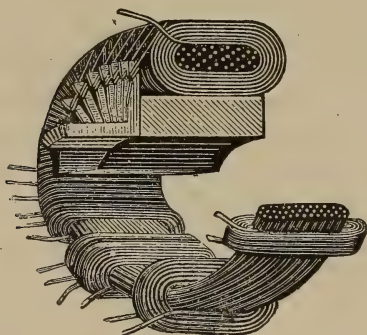
An essential difference between continuous and alternating current machines is that the former may be self-exciting, whereas the latter must have a separate excitor or must be a magneto machine. The cores of the electro-magnets, it may be mentioned, are of cast iron, in which there is always a feeble residual magnetism. It is also easier to magnetize iron than steel, although, when the latter is once magnetized, it retains its magnetism for an indefinite period.

It is not within the province of this work to describe in detail all the forms of dynamos, it being sufficient for our purpose to discuss those which are adapted to and are used for electro-plating uses. If we mention the Gramme machine first, it is not because it is superior to other machines, but because M. Gramme, its inventor, was the first to utilize the idea suggested by Dr. Pacinotti, of using an iron ring as a revolving electro-

magnet, which, in place of having fixed revolving poles, had poles which traveled continuously through the whole circumference of the ring.

Fig. 28 shows the Gramme armature in such a way as to allow its construction to be seen. The core or centre of the ring consists of a bunch of soft iron wires. The wire system wound about the core is formed of different spools, the initial wire of which is soldered to the terminal wire of the neighboring spool, so that all the spools of the ring form a single uninterrupted conductor. The soldered places lie all on one side of the ring, and are fastened to flat copper strips bent at right angles and insulated from one another by a non-conducting

FIG. 28.

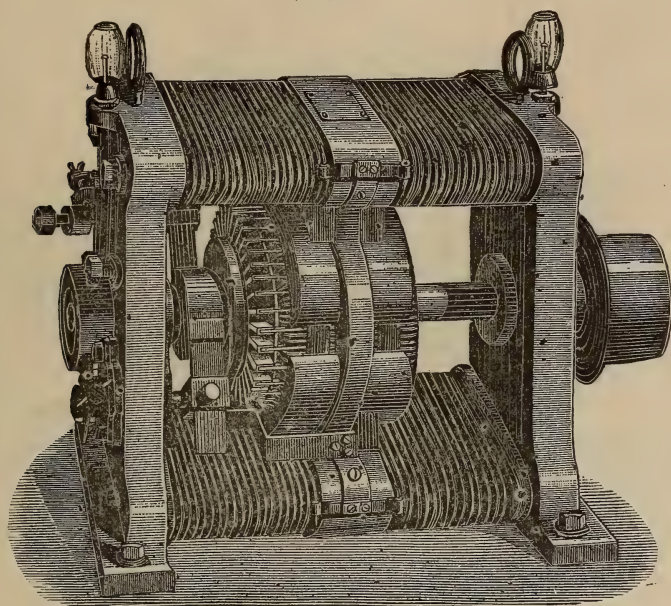


mass which forms the commutator through which the axle passes. The armature revolves between the poles of the electro-magnets secured to the side of the machine, as shown in Fig. 29. As the ring is revolved a current is generated and flows out with every change in its position. The current so made is carried out by wire brushes which press upon the terminal plates of the wires in the ring.

In the modern Gramme dynamos (Fig. 30) for galvanoplastic purposes, which have to furnish a considerable volume of current of slight electro-motive force, the inducing magnets are surrounded by broad copper bands instead of being wound about with copper wire, and the armature is built up of stout

copper rods, because the less resistance the copper windings have, the greater the volume of current which is produced, while, *vice versa*, the tension increases with their resistance. Hence, machines for electro plating purposes, which have to furnish quantities of current of slight tension, are wound about with stout copper wire, while those for illuminating purposes, which must furnish currents of high tension, are wound about with thin copper wire. For this reason machines constructed

FIG. 29.



for galvano-plastic use and for nickeling, coppering, brassing, etc., are not suitable for illuminating purposes, and *vice versa*, machines constructed for electric lighting cannot suitably be employed for plating purposes.

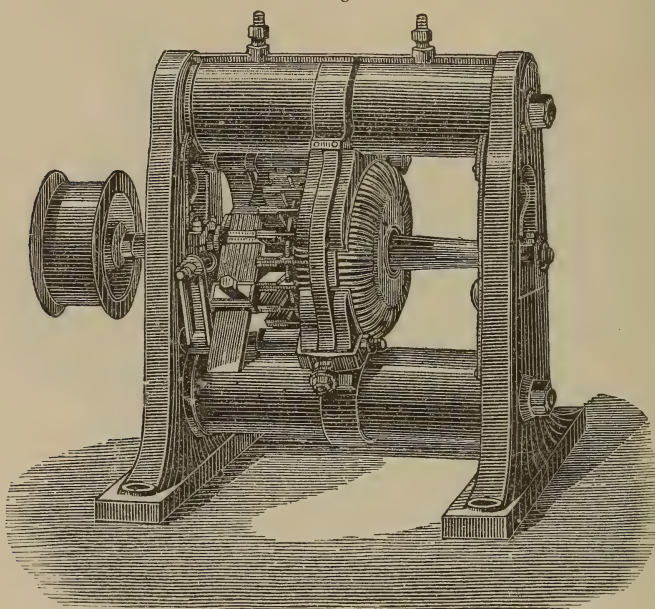
A disadvantage of the Gramme machine is that the only portion of the copper windings on the outside of the ring armature is in the magnetic field of the poles of the electro-magnets, so that only a comparatively small portion of the armature is ex-



posed to the inductive action of the magnets. Hence, in order to furnish correspondingly strong currents, the ring armature must revolve very rapidly, the three sizes or numbers of Gramme machines mostly employed for galvano-plastic purposes making in fact from 1500 to 2000 revolutions per minute, whereby the bearings are more rapidly worn out than with machines running at less speed, and, besides, more power is consumed.

This evil led S. Schuckert, of Nuremberg, to construct a ma-

FIG. 30.

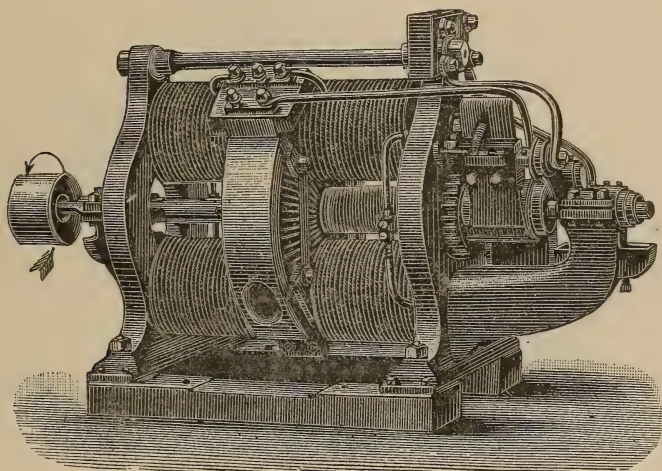


chine in which a *flat* ring is successfully used as an armature, which stands almost entirely under the inductive influence of the electro-magnets. Schuckert's flat ring machine is shown in Fig. 31. The core of the flat ring consists of thin sheet ribbands insulated one from another, whereby greater solidity is attained. The commutator and brushes are similar to those of the Gramme machine. The number of revolutions varies for the different size machines from 500 to 1500 per minute. It is

almost noiseless in action and is exceedingly well constructed. The formation of sparks on the contact surface of the brushes with the commutator is scarcely perceptible, which secures the durability of the latter.

The building of flat-ring machines has recently been abandoned by the firm, and they construct now a dynamo of the drum-armature type. In consequence of the magnetic properties of this dynamo, the quantity of copper upon the armature can be considerably decreased, greater working stability being thereby imparted to the most sensitive portion of the machine. The

FIG. 31.



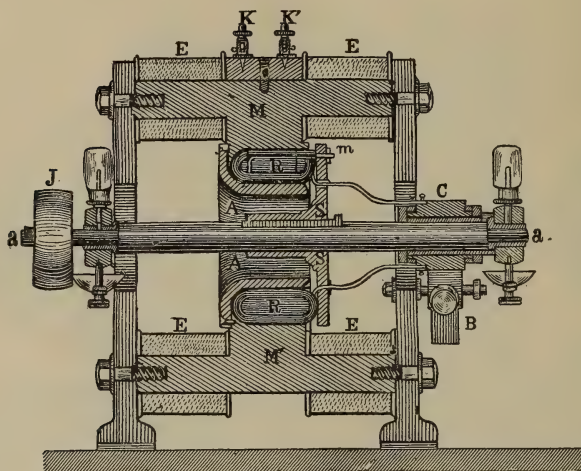
armature is a massive cylinder of soft iron sheets, which are thoroughly insulated from each other. They are closely pressed together enclosing the axis. Parallel to the latter run upon the circumference a number of grooves for the reception, with sufficient insulation, of the covered copper wires, which are thereby also protected from injuries from the outside. The commutator consists of hard bronze, or for dynamos of higher current strength of electrolytic copper.

Fein, of Stuttgart, has endeavored to overcome the defect of the Gramme machine in a different manner. In his machines

the polar extensions of the magnets  $M$  and  $M'$  (Fig. 32) are elongated to a sort of drum,  $A A$ , which leads into the interior of the armature ring, whereby the greater portion of the windings is also brought into the magnetic fields of the electro-magnets.

The machines built by Siemens & Halske, in which the drum-armature invented by Hefner-Altenbeck is used, show a different construction from those previously described. A detailed explanation of the drum-armature would lead us too

FIG. 32.



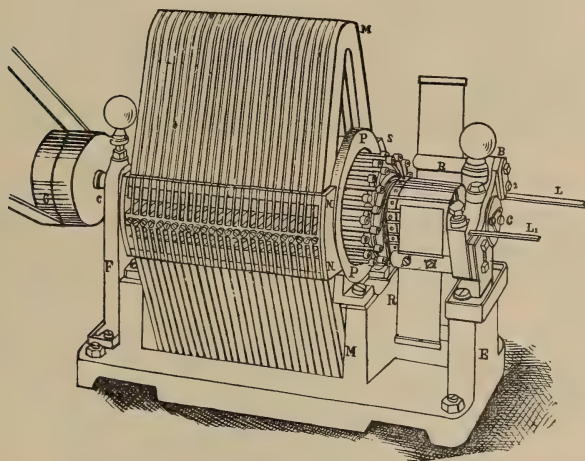
far. It consists of a hollow iron cylinder, which revolves with the shaft, and about which the wires are wound parallel to the revolving axis in such a manner that no wire-windings are in the interior of the core (cylinder). The wire spirals wound about the cylinder are divided into sections, which are so connected one with another as to form a single cohering wire conductor. The terminal wires of the separate sections are connected to the segments of the commutator, so that both the currents generated in the wire system always meet from an opposite direction in two portions of the commutator opposite

to one another. The commutator is constructed according to the Gramme system, and has, of course, as many segments as there are sections wound upon the cylinder. A real advantage of the machine is that the greater portion of the wire-windings of the cylinder-armature is in the magnetic field.

Fig. 33 shows a Siemens & Halske magneto-electric machine with cylinder-armature.

Two series of 25 V-shaped magnets each are placed above and below, so that their poles of a similar name are opposite to

FIG. 33.



one another, the poles of a similar name of the upper and lower magnets being connected one with another by arched pieces of soft iron. In the space thus formed between the upper and lower magnets, the cylinder-armature revolves, the generated currents being carried away from the commutator by the brushes  $R$  and  $R'$ .

In Siemens & Halske's dynamo-electric machines for electro-metallurgical purposes (Fig. 34) the plate magnets are wound about with square copper rods, in smaller machines with stout copper wire, while instead of spirals the armature carries cop-



per ribands, which are connected with the commutator by suitably bent pieces.

FIG. 34.

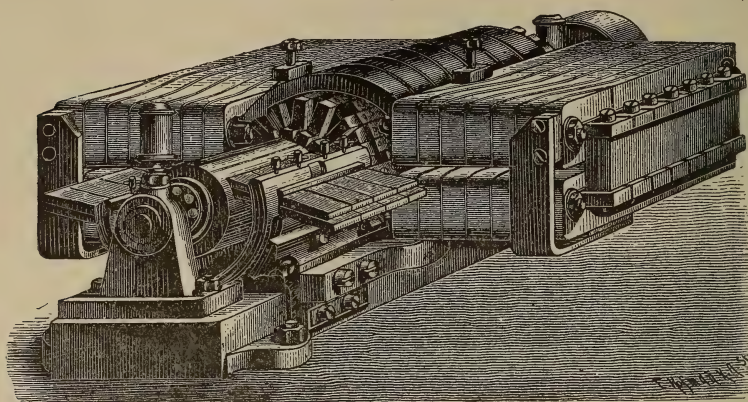
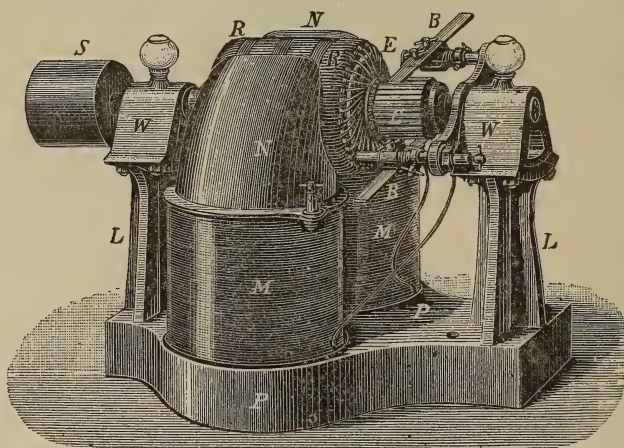


Fig. 35 shows the Kröttlinger machine constructed by Kröttlinger, of Vienna. It consists of a strong iron base, *P*, from

FIG. 35.



which rise two short cylindrical electro-magnets, *M M*, which have a semicircular shaft on the upper end *N*, and closely embrace the ring *R*. The standards *L* are cast in one piece

with the base *P*, and carry the bearing *W W*. The core of the ring *R* consists of separate disks of cast iron arranged alongside one another upon the shaft so as to form a massive cylinder which is wound about with stout copper wire. The inductive spools of the ring are connected by means of screws with phosphor-bronze plates of the commutator *C*. In this dynamo, which is of the shunt-wound type, the current generated in the ring does not pass first through the electro-magnets, and then as working current into the conductor, but the greater portion passes as working current from the brushes *B B* into the conductor to the baths, while the other comparatively smaller portion of current passes through the wrappings of the electro-

FIG. 36.

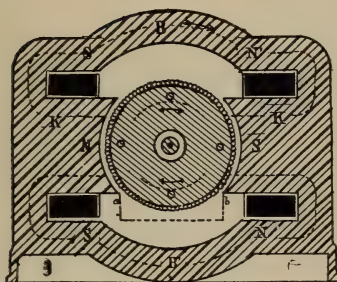
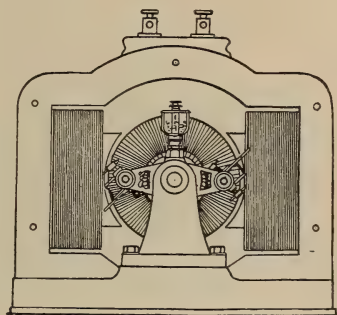


FIG. 37.



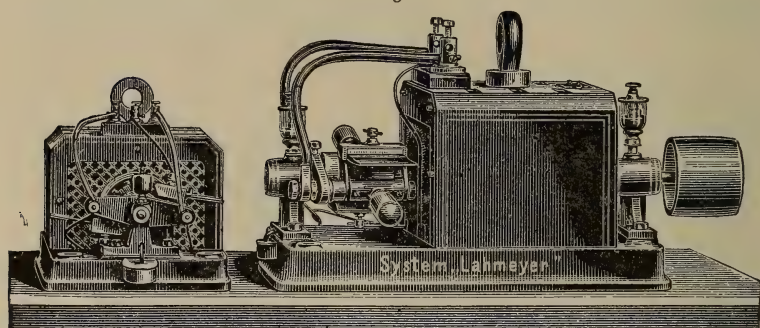
magnets *M M*, and excites them. As in Schuckert's machines, a regulator with resistance coils may be inserted in the circuit of the current, which allows of the generation of the current being controlled within quite wide limits, as may be desired. The advantages of this dynamo consist in the large masses of iron of short length with a large cross-section of the cores of the electro-magnets, the standards and base being made in one piece, and in the durable iron core of the ring. The formation of sparks is slight.

The Lahmeyer dynamo, shown in Figs. 36, 37, and 38, in cross-section, open side view, and perspective exterior view, fulfils the three principal conditions of a good dynamo, viz.,

great useful effect, discharge of the current without sparks, and solidity of construction. Opposite to the drum-armature or drum-inductor of the machine stand horizontally two short, stout electro-magnet cores, whose ends averted from the armature are connected by a thick iron frame carried above and below around the windings. This electro-magnet frame of soft iron is cast in one piece with the base of the machine, so that no resistance is offered to the lines of force by a joint, while the large iron cross-sections also give rise to but slight magnetic resistance.

The magnetic field of the Lahmeyer machine must be considered as a magnetic circle in so far as the lines of force, which

FIG. 38.



are generated by the spools in the iron everywhere contiguous to them, pass together through both spools, and only ramify outside of them in the re-conducting plates *B B'*. By this favorable disposition, a current of slight strength passing through the wrappings of the electro-magnets produces a strong excitation of the latter.

The armature is of the Siemens cylinder type, but is composed of disks of thin, white sheet-iron insulated one from the other by paper. Several segments of vulcanized fibre, two of which form the face, serve for holding the wrappings of the armature. The latter consists of a single layer of stout copper wire, and this, in conjunction, with the symmetrical disposition



which excludes the scattering of the lines of force as much as possible, effects a discharge of the current without sparks. The space visible in the side view is closed by perforated plates secured by screws, as seen in Fig. 38. This is a further advantage of the machine in so far that all sensitive parts are protected from external injury. Like all dynamos of the cylinder or drum-type, the Lahmeyer dynamo requires a large number of revolutions per minute, but with the slight weight of the armature and the solid construction of the bearings, there is but little danger of the rapid wearing out of the latter.

FIG. 39.

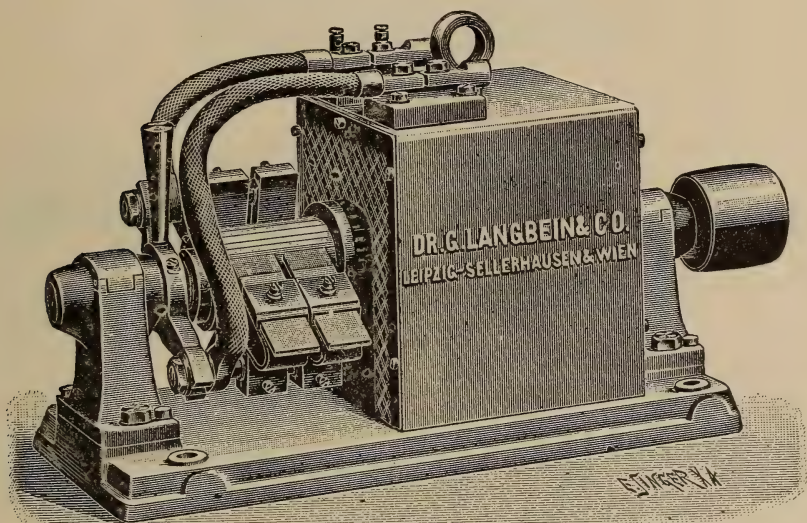


Fig. 39 shows a shunt-wound dynamo constructed by Dr. G. Langbein & Co.

The electro-magnet frame and the foundation plate are cast in one single casting of soft iron, so that no resistance is offered by joints in any part to the lines of force, while the large cross-sections of iron cause a slight magnetic resistance.

The armature, Fig. 40, is of the drum-type, and is built up of round discs of soft sheet iron which are insulated from each



other by paper discs, and pressed together and screwed upon the shaft. Grooves in the circumference of the armature, which run parallel to the axis, serve for the reception of the armature winding, the latter being insulated from the armature by paste-board. The drum-armature is surrounded by two short, exceedingly powerful, electro-magnet cores, arranged in vertical position radially opposite one to the other. Their ends project parallel to the circumference of the armature, and their sloping form prevents the jerky formation of the current, the latter being yielded to the commutator almost without any sparking. In consequence of an abundant use of cross-sections of copper, the degree of efficiency is an excellent one.

The commutator is, according to the Gramme system, con-

FIG. 40.

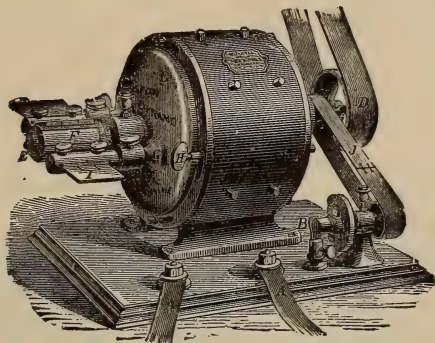


structed of bronze rich in copper. The journal bearings are made of phosphor-bronze, and in order to decrease friction are highly polished, as well as the portions of the steel shaft running in them. The journals are provided with automatic ring lubrication. The dynamo being in box form entirely enclosed, all sensitive portions are protected from injury. In consequence of the use of large cross-sections of copper upon the armature and the magnet-winding, the number of revolutions is moderate, and consequently the consumption of power and the wear of the journals are slight.

It may be of interest to give here a brief resumé of what may be called the evolution of the dynamo for plating purposes in the United States, with special reference to the machines built by the Hanson & Van Winkle Co., of Newark, N. J.

The first machine for electro-plating in the market was the Weston dynamo, Fig. 41, which was first manufactured in 1876.

FIG. 41.



Being of small dimensions, of compact form, and yielding an abundant current, it was well adapted to the wants of the electro-plater, and hence it met with pronounced success, and to it can be traced the sudden development of electro-plating and electrotyping in this country. Some of these machines are still in use.

FIG. 42.

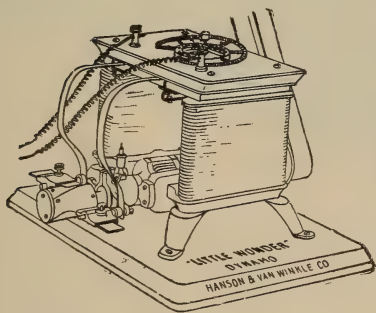
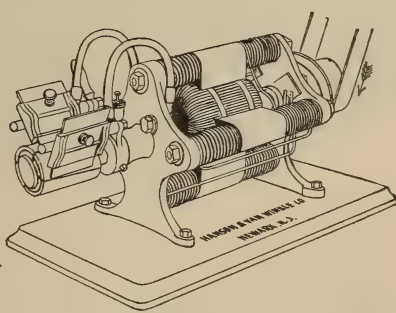


FIG. 43.

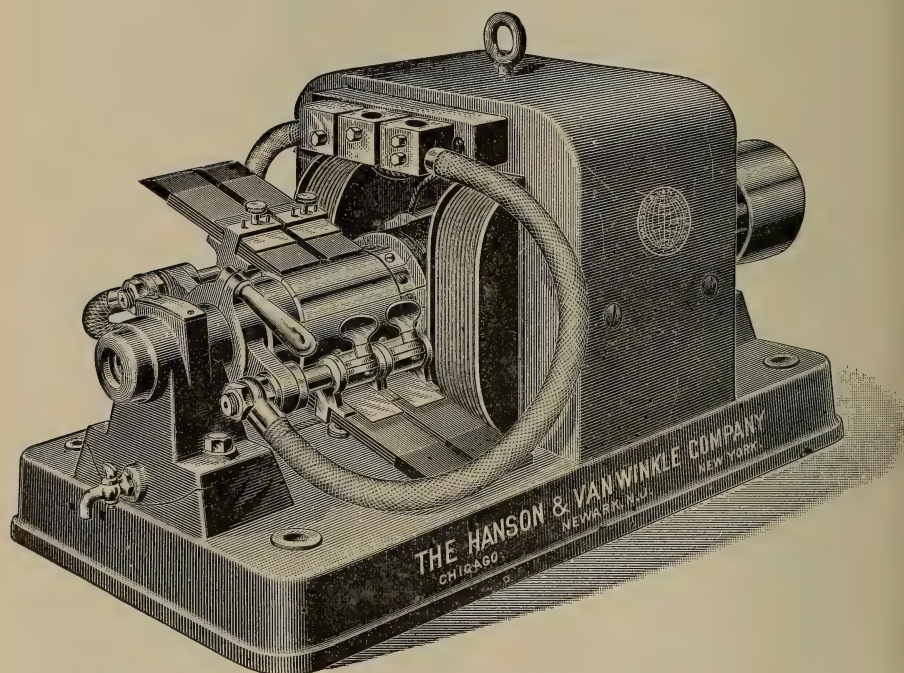


In 1885, the "Little Wonder" dynamo, Fig. 42, was introduced, and became very popular. In 1886, the Hanson & Van Winkle Co. began manufacturing the "Wonder" dynamo, Fig.

43. It embodied many new improvements and it was thought perfection had been reached. However, in 1891, electrical science had developed so many entirely new features that the above-mentioned firm brought out a still more improved machine, the H. and V. W. dynamo.

However, the latest improvement in plating dynamos manufactured by the Hanson & Van Winkle Co., is the *new* H. & V. W. dynamo, which is shown in Figs. 44, 45, and 46.

FIG. 44.

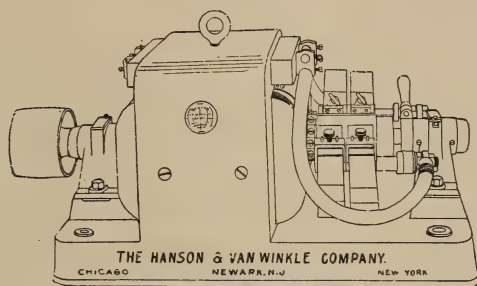


This new slow-speed, iron-clad, compound-wound machine reaches the highest degree of excellence. The distinctive feature of this machine is the construction of the field magnets and of the frame, which are cast in one single casting. This construction gives a magnetic field of much greater intensity than can otherwise be obtained, and entirely prevents all waste-

ful induced currents in magnets and pole pieces, points of the greatest importance and essential to high efficiency.

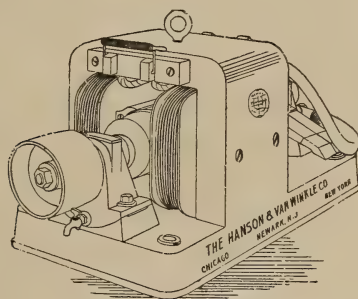
The magnetic circuit is of unusually low resistance by reason of its shape, its shortness and the superior quality of iron used.

FIG. 45.



There is no magnetism in the frame, base or shaft, as the magnets are supported at some distance from the base of the machine. There is, therefore, no opportunity for magnetic leakage, and besides the whole is enclosed by a shield or case of metal.

FIG. 46.



The regulation of the voltage is entirely automatic, holding a constant voltage from no load to the full capacity of the dynamo. This result has heretofore been accomplished by the use of resistance rheostats, etc., requiring constant attention, in case the number of square feet of surface in the vats is varied,



which is liable to burn the work if a light load is in the tanks. This has been overcome by the compound winding. A saving in the consumption of power required is also made, as the machine adjusts itself immediately to whatever load is placed thereon, from a single piece in the vats or to the full load of the dynamo.

The armature is of a drum type and is built up of thin disks, all of which are securely fastened to the shaft. The winding is a modification of the Siemens method, and the mode of connecting and collecting the current from the same produces a current as steady as any battery could give.

The armature is so proportioned that it has but little idle wire over the heads and is only wound with one layer of wire. The winding is done with the greatest care, and so insulated that there is little danger of short circuiting and burning out. The ends of the armature and the electrical connections are thoroughly covered, thereby protecting them from copper dust or dirt of any kind.

The necessary voltage is secured by revolving a comparatively small number of coils of wire in a powerful magnetic field, rather than by using a large number of coils and weak field, as is the usual practice. The small amount of wire on the armature accounts in a great measure for the absence of sparking at the brushes.

The commutator is insulated with mica, and is of ample length of surface to secure the best action and reduce the wear to a minimum.

The segments are pure tempered copper, the most durable material known for the purpose, and when necessary may be removed without returning the machine to the factory. The shaft is made of the best crucible steel, of great diameter in its central part, accurately turned and finished in the best possible manner. All armatures of the same size are interchangeable.

The slow speed of this dynamo is a most important point for consideration, it being run at about half the speed of other makes of plating machines of equal cost.

The journals are of generous dimensions, resting in bronze bearings of the finest quality. They are self-aligning and self-oiling, with carrier rings in each bearing. The oil wells are of ample size to hold enough oil for two or three months' supply. In this manner the bearings are automatically oiled by the motion of the shaft, and they require no attention beyond a periodical examination and renewal of oil.

The advantages claimed by the manufacturers for this dynamo are as follows: 1. High efficiency; therefore economy of power. 2. Current generated without any sparking at the brushes; therefore steady current, and small wear of brushes and commutator. 3. Solidity of construction; therefore safety against interruptions from external injury, and no risk in transportation. 4. Accessibility of the different parts and simplicity of design. 5. No scattering of the lines of force; therefore no *external magnetism* or the attraction of pieces of iron, or the magnetizing of watches and compasses, etc. 6. Perfect regulation. 7. Self-oiling bearings. 8. Ninety-five per cent. efficiency. 9. Slow speed. 10. Self-aligning bearings. 11. Mechanical perfection. 12. Works equally well with light or heavy load, and will do more work for the same power and first cost than any other make of plating machines now on the market.

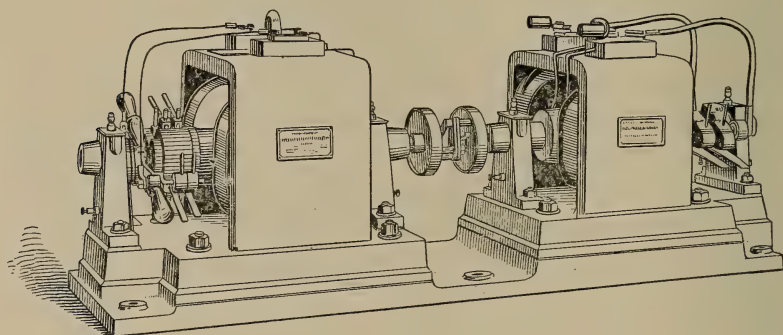
Direct connected motors to machines of various kinds are becoming so generally used that the manufacturers of the H. & V. W. dynamo are now providing their dynamos with motors of 110 and 220 volts direct, and mounted on same base so as to insure greater regularity of current where owing to a distance from the engine, slipping of belt, etc., the speed may show a variation of 5 to 10 per cent.

Whenever possible, it is advisable to avoid the transmission of the mechanical energy to the pulley of the dynamo-machine by means of belts, and to use for driving the dynamo a special electro-motor which is supplied with current from a lighting circuit of a central plant.

If an electro-motor is used, it is best to connect the generator

and motor directly by joining (flanging) the shafts of the two machines. If such a system, Fig. 47, is to be set in motion, the current must be successively conducted into the armature-winding of the motor, the magnetic field of the latter having been previously excited. Both of these problems are solved by starting-resistances of wire spirals placed in front of the armature of the motor, which gradually brings the tension of the current to the amount of the conduit or working tension. If the electro-motor would suddenly, without starting resistances, be coupled to the circuit of the central plant, it might happen that in consequence of the high induced current formed

FIG. 47.



by induction, the insulation of the armature wires would be pierced, and the machine become disabled.

Detailed descriptions of other machines, such as the Müller, Mather, Elmore, Bürgin, Gülcher, etc., would needlessly lengthen this chapter. The great impulse which the art of electro-plating has in modern times received is largely due to the important improvements that have been made in the construction of dynamo-electric machines, by which mechanical energy generated by the steam-engine or other convenient source of power may be directly converted into electrical energy. Without dynamos it would be impossible to electro-plate large parts of machines, architectural ornaments, etc., which are thus

protected from the influence of the weather. They may safely be credited with having called into existence an important branch of the electro-plating art, viz., nickel-plating, and especially the nickel-plating of zinc sheets, as well as sheets of copper, brass, steel, and tin, which would have been impossible if the manufacturer had to rely upon the generation of the electric current by batteries. The latter, at the very best, are troublesome to manage; they only give out their full power when freshly charged, and as the chemical actions upon which they rely for their power progress, they deteriorate in strength and require frequent additions of acids and salts to be freshly charged, and their use demands constant vigilance and attention. Even when working on a small scale, it is cheapest to procure a small gas or other motor for driving a small dynamo, the lathes, and grinding and polishing machines.

To make it possible for the manufacturer of dynamos to suggest the most suitable machine, the following data should be submitted to him:—

1. Variety, size, and number of the baths which are to be fed by the machine.
2. The average surface of the articles in the bath, or their maximum surface, and the metals of which they consist.
3. Whether at one time many and at another time few articles are suspended in the bath.
4. The distance at which the machine can be placed from the baths.
5. The power at disposal.

#### D. SECONDARY ELEMENTS (ACCUMULATORS).

In the theoretical part of this treatise, the polarizing current has been referred to. Although the polarization of metal plates for the production of secondary currents had previously been employed by Ritter, the construction of practically useful accumulators was first accomplished by Planté. He found that lead plates dipping into dilute sulphuric acid were specially well adapted for the production of secondary currents, and he



arranged the accumulators as follows: In a square glass vessel filled with 10 per cent. sulphuric acid solution, a large number of lead plates were suspended in such a way that all plates with even numbers, hence, 2, 4, 6, and so on, were electrically connected one with the other, while the plates with uneven numbers, hence, 1, 3, 5 and so on, were also in contact with each other. Between the separate plates dipping in the acid was sufficient space to prevent them from touching one the other. One series of the plates served as positive, and the other as negative, electrodes. Now by conducting an electric current through the plates lead peroxide is formed upon the positive electrodes, and by interrupting the current and combining the series of electrodes with each other, the peroxide is reduced to metallic lead, and the negative lead plates are oxidized, whereby an electric discharge takes place, the secondary or accumulator-current passing through the metallic connection of the series of plates.

For the production, in the above described manner, of currents of high power and longer duration, the plates have to be suspended as closely together as possible without danger of contact, in order to decrease the internal resistance of the element as far as practicable, and also to increase the quantity of lead peroxide.

However, the formation of the layer of lead peroxide upon the lead plates of Planté's accumulator was a slow process, and for this reason Faure used lead grids. The square openings in the negative plates are filled with a paste of litharge and sulphuric acid, and the positive plates with one of minium and sulphuric acid. The current reduces the litharge and peroxidizes the minium.

Planté showed that accumulators *form* by usage—that is to say that up to a certain point their capacity is greater the more frequently they have been charged and discharged. By repeated oxidation and deoxidation the lead acquires a spongy structure, and gradually a large mass of metal takes part in the reaction. The *formation* is accelerated by immersing the fresh

plate for a day or two in nitric acid diluted with its own volume of water.

With well-formed accumulators from 10,000 to 20,000 coulombs can in practice be stored for each kilogramme (2.2 lbs.) of lead. Planté obtained still higher numbers, 40,000, or even 60,000. As the discharge usually takes place under an electromotive force of about two volts, the available energy in the ordinary case is 20,000 to 40,000 joules per kilogramme of lead. Of course this energy is expended in a longer or shorter time according to the strength of the current.

In practice the capacity of an accumulator is frequently expressed in *ampere-hours*, an ampere-hour being the quantity of electricity which passes through the circuit in an hour, when the strength of the current is 1 ampere.

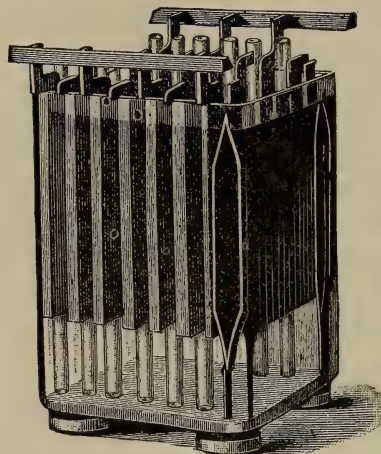
1 ampere-hour = 3600 coulombs. Thus in practice from 3 to 6 ampere-hours may be stored for each kilogramme of lead.

It is not necessary to enter here upon a description of the various constructions of the lead plates, but the chemical processes which take place in the accumulator may be briefly referred to. Regarding these processes several theories have been advanced, for instance, by Elbs, Liebenow and Loeb, and others, but it has not yet been definitely settled which of these views is correct. There can, however, be no doubt that the lead sulphate which is formed by the action of the sulphuric acid upon the lead plays the principal role, in so far as the charging and discharging of the accumulator are effected only by the decomposition and subsequent reformation of the lead sulphate.

Elbs's theory is as follows: As lead is bivalent and quadrivalent, after the decomposition of the lead sulphate to lead and sulphuric acid, the latter combines with the lead sulphate which remains undecomposed to lead bisulphate. This formation of lead bisulphate must chiefly take place on the positive electrodes, since the anion (the sulphuric acid) travels to the positive pole, and by the action of the water the lead bisulphate is decomposed to lead peroxide and free sulphuric acid.

Liebenow and Loeb assume that in charging there are formed, by the decomposition of the lead sulphate, sulphuric acid-ions, lead-ions, and by the co-operation of water, lead peroxide-ions and hydrogen-ions. The anions, sulphuric acid and lead peroxide, travel to the positive pole, and the kations, lead and hydrogen, to the negative pole. However, on both the poles only those ions are separated for the precipitation of which the least work is required, or in other words, whose decomposition-point is lowest, which in this case are lead peroxide and lead. Since, however, on account of the slight solubility and dis-

FIG. 48.



sociation of lead salts, the ions in the immediate neighborhood of the electrodes would soon be exhausted, further charging can only take place when from the lead sulphate formed on the electrodes, fresh molecules are brought into solution, by the dissociation of which the precipitated ions are replaced, and charging is only finished when all the lead sulphate is dissolved and separated as lead peroxide and lead-sponge. With a further passage hydrogen-ions, which possess the next highest decomposition-point, are separated. The above-described

process which in charging takes place by the action of the current, progresses in a reverse sense when, by connecting the positive and negative electrodes, the discharge is rendered possible, whereby the accumulator-current becomes available for exterior work. The lead peroxide is reduced and lead and lead sulphate are formed, while on the negative electrode the lead sponge is oxidized, sulphate of lead being also formed at the same time.

Fig. 48 shows a common form of an accumulator. The separate electrodes are insulated from each other by glass tubes, the entire system being secured by lead springs which press the electrodes against the glass tubes. Small accumulator cells are of glass, hard rubber or celluloid, and larger ones of wood lined with lead.

The sulphuric acid used for filling should be free from chlorine and metallic impurities, and have a specific gravity of 1.21.

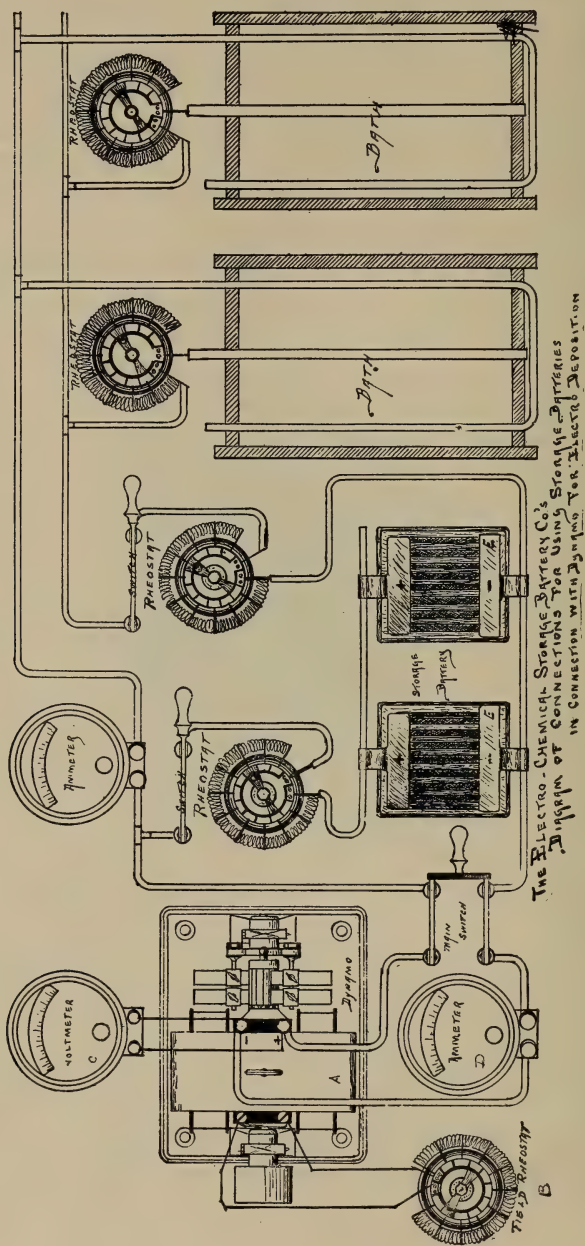
The first charging of the accumulator should be effected immediately after pouring in the acid, and be continued until vigorous evolution of gas takes place on the positive and negative electrodes which is generally the case in about 20 hours. When charging is finished the accumulator is ready for work. Detailed directions for the management of accumulators may here be omitted, they being furnished by the manufacturers of the various systems.

The diagram Fig. 49 shows the connections of a plant as installed by the Electro-Chemical Storage Battery Co., of New York.

By suitable manipulation of the switches and rheostats it is possible to make the following connections: 1. The dynamo alone can be used on the baths. 2. The batteries alone can be used on the baths. 3. The dynamo can be used on the baths and the batteries charged with the excess-current, while at the same time steadying the dynamo current. 4. The dynamo and batteries can be used in multiple on the baths, giving a greatly increased capacity.



FIG. 49.



## IV.

# PRACTICAL PART.

---

### CHAPTER IV.

#### ARRANGEMENT OF ELECTRO-PLATING ESTABLISHMENTS IN GENERAL.

ALTHOUGH rules valid for all cases cannot be given, because modifications will be necessary according to the size and extent of the establishment, the nature of the articles to be electro-plated, and the method of the process itself, there are, nevertheless, certain main features which must be taken into consideration in arranging every establishment, be it large or small. Only rooms with sufficient light should be used, since the eye of the operator is severely taxed in judging whether the articles have been thoroughly freed from fat, in recognizing the different tones of color, etc. A northern exposure is especially suitable, since otherwise the reflection caused by the rays of the sun may exert a disturbing influence. For larger establishments the room containing the baths should, besides side-lights, be provided with a sky-light, which, according to the location, is to be protected by curtains from the rays of the sun.

Due consideration must be given to the frequent renewal of the air in the rooms. Often it cannot be avoided that the operations of pickling, etc., must be carried on in the same room in which the baths are located. Especially unfavorable in this respect are smaller establishments working with batteries, in which the vapors evolved from the latter are added to the other vapors, and render the atmosphere injurious to health.

Hence, if possible, rooms should be selected having windows on both sides, so that by opening them the air can at any time be renewed, or the baths and batteries should be placed in rooms provided with chimneys. By cutting holes of sufficient size in the chimneys near the ceilings of the rooms, the discharge of injurious vapors will in most cases be satisfactorily effected.

To those working with Bunsen elements, it is recommended to place them in a closet varnished with asphalt or ebonite lacquer, and provided with lock and key. The upper portion of the closet should communicate by means of a tight wooden flue with a chimney or the open air.

Since the baths work with greater difficulty, more slowly and more irregularly below a certain temperature, provision for the sufficient heating of the operating rooms must be made. Except baths for hot gilding, platinizing, etc., the average temperature of the plating solutions should be from  $64.5^{\circ}$  to  $68^{\circ}$  F., at which they work best; it should never be below  $59^{\circ}$  F., for reasons to be explained later on. Hence, for large operating rooms such heating arrangements must be made that the temperature of the baths cannot fall below the minimum even during the night, otherwise provision for the ready restoration of the normal temperature at the commencement of the work in the morning has to be made. Rooms heated during the day with waste steam from the engine, generally so keep the baths during the winter—the only season of the year under consideration—that they show in the evening a temperature of  $64.5^{\circ}$  to  $68^{\circ}$  F., and if the room is not too much exposed, the temperature, especially of large baths, will only in rare cases fall below  $59^{\circ}$  F. For greater security the heating pipes may be placed in the neighborhood of the baths, but if this should not suffice to protect the baths from cooling off too much, it is advisable to locate in the operating room a steam conduit of small cross-section fed from the boiler and to pass steam for a few minutes through a coil of a metal indifferent to the plating solution suspended in the bath. In this manner baths of 1000 quarts,

which, on account of several days' interruption in the operation, had cooled to  $36^{\circ}$  F., were in ten minutes heated to  $68^{\circ}$  F. For smaller baths it is better to bring a small portion of them in a suitable vessel to the boiling-point, over a gas flame, and add it to the cold bath, and if, after mixing, the temperature of the bath is still too low, repeating the operation.

Another important factor for the operating rooms is the convenient renewal of the waters required for rinsing and cleansing. Without water the electro-deposition of metals is impossible; the success of the process depending in the first place on the careful cleansing of the metallic articles to be electroplated, and for that purpose water, nay, much water, hot and cold, is required, as will be seen in the section treating on the "Preparation of the Articles." Large establishments should, therefore, be provided with pipes for the admission and discharge of water, one conduit terminating as a rose over the table where the articles are freed from grease. In smaller establishments, where the introduction of a system of water-pipes would be too expensive, provision must be made for the frequent renewal of the cleansing water in the various vats.

In consequence of rinsing and transporting the wet articles to the baths much moisture collects upon the floor of the operating rooms. The best material for floors of large rooms is asphalt, it being, when moist, less slippery than cement. A pavement of brick or mosaic laid in cement is also suitable, but has the disadvantage of cooling very much. The pavement of asphalt or cement should have a slight inclination, a collecting basin being located at the lowest point, which also serves for the reception of the rinsing water. Wood floors cannot be recommended, at least for large establishments, since the constant moisture causes the wood to rot. However, where their use cannot be avoided, the places where water is most likely to collect should be strewn with sand or saw-dust, frequently renewed, or the articles when taken from the rinsing water or bath be conveyed to the next operation in small wooden buckets or other suitable vessels.



The operating room should be of such a size as to permit the convenient execution of the necessary manipulations. Of course, no general rule can be laid down in this respect, as the size of the room required depends on the number of the processes to be executed in it, the size and number of articles to be electro-plated daily or within a certain time, etc. However, there must be sufficient room for the batteries or dynamo, for the various baths, between which there should be a passageway at least twenty inches wide, for the table where the articles are freed from grease, for the lye kettle, hot-water reservoir, saw-dust receptacle, tables for tying the articles to hooks, etc.

The rooms used for grinding, polishing, etc., also require a good light in order to enable the grinder to see whether the article is ground perfectly clean, and all the scratches from the first grinding are removed. Where iron or other hard metals are ground with emery, it is advisable to do the polishing in a room separated from the grinding shop by a close board partition; because in the preparatory grinding with emery, which is done dry, without the use of oil or tallow, the air is impregnated with fine particles of emery, which settle upon the polishing disks and materials, and in polishing soft metals cause fine scratches and fissures which spoil the appearance of the articles, and can be removed only with difficulty by polishing. Hence, all operations requiring the use of emery, or coarse grinding powders, should be performed in the actual grinding-room, as well as the grinding upon stones and scratch-brushing by means of rapidly revolving steel scratch-brushes. Articles already electro-plated are, of course, scratch-brushed in the plating-room itself, either on the table used for freeing the articles from grease, or on a bench especially provided for the purpose. In the polishing room are only placed the actual polishing machines, which by means of rapidly revolving disks of felt, flannel, etc., and the use of polishing powders, or polishing compositions, impart to the articles the final lustre before and after electro-plating. The formation of dust in the

polishing rooms is generally over-estimated; it is, however, sufficiently serious to render necessary the separation by a close partition of the polishing rooms from the electro-plating room, otherwise the polishing dust might settle upon the baths and give rise to various disturbing phenomena. In rooms in which large surfaces are polished with Vienna lime, as, for instance, nicked sheets, the dust often seriously affects the health of the polishers, especially in badly ventilated rooms, and in such cases it is advisable to provide an effective ventilator. If this cannot be done, wooden frames covered with packing-cloth, placed opposite the polishing disks, render good service; the packing-cloth, by being frequently moistened, retaining a large portion of the polishing dust.

For grinding lathes requiring the belt to be thrown off in order to change the grinding, it is best to place the transmission carrying the belt-pulleys at a distance of about three feet from the floor, while for lathes with spindles outside the bearings the transmission may be on the ceiling or wall. The revolving direction of the principal transmission should be such as to render the crossing of the belts to the grinding and polishing machines unnecessary, otherwise the belts on account of the great speed will rapidly wear out.

#### ELECTRO-PLATING ARRANGEMENTS IN PARTICULAR.

The actual electro-plating plant consists of the following parts: 1. *The sources of current* (batteries or dynamo-electric machines) *with auxiliary apparatus*. 2. *The current-conductors*. 3. *The baths*, consisting of the vats, the plating solution, the anodes, and the conducting rods with their binding-screws. 4. *The apparatuses* for cleansing, rinsing, and drying. The sources of current have already been discussed in Chapter III, p. 35, and the laws governing the suitable coupling of the elements on p. 19.

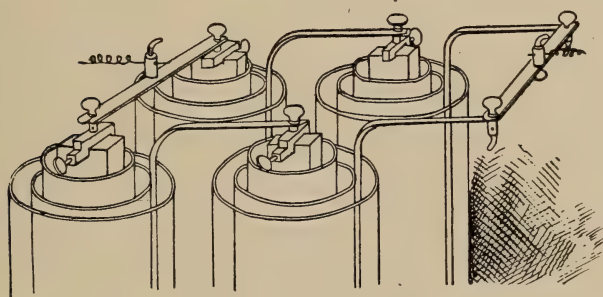
A. *Arrangement with elements*.—In working with elements it is first necessary to have a clear idea of the area of the articles which are to be *at one time* electro-plated in a bath, and of the

magnitude of the resistance opposed by the bath to the current. This and the size of the anodes show how many elements must be put together for a battery, and how the elements are to be coupled. Suppose we have a nickel bath which requires for its decomposition a current of 2.5 volts of electro-motive force or tension. Now since, according to p. 43, a Bunsen element develops a current of 1.88 volts, the reduction of the nickel cannot be effected with one such element alone, but two elements must be coupled for tension one after the other, whereby, leaving the conducting resistance of the wires out of consideration, an electro-motive force or tension of  $2 \times 1.88 = 3.76$  volts is obtained, with which the decomposition of the solution can be effected. If, on the other hand, we have a silver bath which requires only  $\frac{1}{2}$  volt for its decomposition, we do not couple two elements one after the other, because the electro-motive force of a single element suffices for the reduction of the silver. On p. 19 it has been seen that by coupling the elements one after the other (coupling for tension) the electro motive force of the battery is increased, but the quantity of current is not increased, and that to attain the latter the elements must be coupled alongside of one another (coupled for quantity). Hence in a group of, for instance, three elements coupled one after another, only one single zinc surface of the elements can be considered effective in regard to the quantity of current. Now, the larger the area of articles at the same time suspended in the bath is, the greater the number of such effective zinc surfaces of the group of elements to be brought into action must be; and, if for baths with medium resistance, it may be laid down as a rule that the effective zinc surface must be at least as large as the area of the articles, provided the surface of the anodes is at least equal to the latter, the approximate number of elements and their coupling for a bath can be readily found. Let us take the nickel bath, which, as above mentioned, requires a current of 2.5 volts, and for the decomposition of which two elements must, therefore, be coupled one after the other, and suppose that the zinc surface of the Bunsen elements

is 500 square centimetres, then the effective zinc surface of the two elements coupled one after the other will also be 500 square centimetres; hence a brass sheet  $20 \times 25 = 500$  centimetres can be conveniently nickeled on one side with these two elements, or a sheet  $10 \times 25 = 250$  centimetres on both sides. Now suppose the surface to be nickeled were twice as large, then the two elements would not suffice, and a second group of two elements, coupled one after the other, would have to be joined to the first group for quantity, as shown in Fig. 4, or perspective in Fig. 50. Three times the object surface would require three groups of elements, and so on.

However, this, to a certain extent, empirical determination of

FIG. 50.



the number of elements required for plating surfaces of definite measure may be abandoned, and we may avail ourselves of a more exact determination according to electrical values, since at the present time the electrical relations of the baths are accurately known and the performances of the elements, as well as of the dynamos, are specified according to current quantity and current tension.

As regards the result of the process of deposition, the first requisite which has to be taken into account is that a sufficient quantity of current acts upon the surface to be plated, and the next that the current possesses the necessary tension for the decomposition of the bath. Now the current quantity which is required for the correct formation of the deposit upon 1

L. of C.



square decimeter \* =  $10 \times 10$  centimeters † (100 square centimeters) may be designated as the current-density, and in the plating processes described later on, the suitable current-density is always given. If now, for instance, this current-density for a nickel bath is 0.6 ampère per sq. dcm., the tension 2.5 volts and the largest surface to be plated in the bath 50 cm.  $\times$  20 cm. = 1000 sq. cm. or 10 sq. dcm. a current-strength of at least  $0.6 \times 10 = 6$  ampères would be required. Hence, a medium-large element furnishing 8 ampères would suffice if the tension necessary for the decomposition of the electrolyte did not amount to 2.5 volts. As previously stated, a Bunsen element furnishes about 1.8 volts, and hence, in order to obtain the higher tension, two elements must be coupled one after the other, and the excess, which would be an impediment to the correct formation of the deposit, has to be destroyed by the current-regulator to be described later on, in case it is not preferred to increase the object-surface.

For silvering, the current-density amounts to 0.25 ampère, and, with a slight excess of potassium cyanide, the silver bath requires 1 volt. If now, for instance, an object surface of 55 sq. dcm., which is about equal to 50 large tablespoons, is to be silvered,  $55 \times 0.25 = 13.75$  ampères and 1 volt are required. Hence, two elements of 8 ampères each must be coupled alongside one another in order to obtain 16 ampères current-quantity, and the excess destroyed by the current-regulator.

In giving these illustrations it is supposed the objects are to have a thick solid plating. For rapid plating and a thin deposit a different course has to be followed. Only a slight excess of electro-motive force in proportion to the resistance of the bath being in the above-mentioned case present, reduction takes place slowly and uniformly without violent evolution of gas on the objects, and by the process thus conducted the deposit formed is sure to be homogeneous and dense, since it absorbs but slight

\* 1 square decimeter (sq. dcm.) = 15.501 square inches.

† 1 centimeter (cm.) = 0.394 inch.

quantities of hydrogen, and in most cases it can be obtained of sufficient thickness to be thoroughly resistant. If, however, the operation is to be executed rapidly and without regard to great solidity and thickness of the deposit, the elements have to be coupled so that the electro-motive force is sufficiently large for the current to readily overcome the resistance of the bath. This is attained by coupling three, four, or more elements one after the other, as shown in the scheme Fig. 2. However, such deposits can never be homogeneous, because they condense and retain relatively large quantities of hydrogen.

As regards the filling and other management of the batteries, the reader is referred to pp. 40 to 45, under Bunsen elements. Having seen how many elements are required, and how they have to be coupled to form a battery for certain purposes, the *auxiliary apparatuses* will be next considered.

Only in very rare cases will it be possible to always charge a bath or several baths with the same object-area; and according to the amount of business, or the preparation of the objects by grinding, polishing, and pickling, at one time large, and at another small, areas will be suspended in the bath. Now, suppose a battery suitable for a correct deposit upon an area of, say five square feet, has been grouped together; and, after taking the articles from the bath, a charge of objects only half as large as before is introduced, the current of the battery will, of course, be too strong for this reduced area, and there will be danger of the deposit not being homogeneous and dense, but forming with a crystalline structure, the consequence of which, in most cases, will be slight adhesiveness, if not absolute uselessness. With sufficient attention the total spoiling of the articles might be prevented by removing the objects more quickly from the bath. But this is groping in the dark, the objects being either taken too soon from the bath, when not sufficiently plated, or too late, when the deposit already shows the consequences of too strong a current.

To control the current an instrument called the *rheostat*, *current-regulator*, *resistance board*, or *switch board*, has been con-

structed, which allows of the current-strength of a battery being reduced without the necessity of uncoupling elements. It is evident that the current of a battery, if too strong, can be weakened by decreasing the number of elements forming the battery, and also by decreasing the surface of the anodes, because the external resistance is thereby increased. This coupling and uncoupling of elements is, however, not only a time-consuming, but also a disagreeable, labor; and it is best to use a resistance board with which, by the turn of a handle, the desired end is attained. Figs. 51 and 52 show this instrument.

FIG. 51.

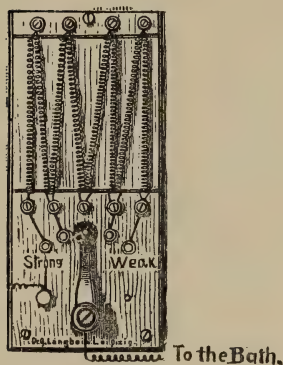
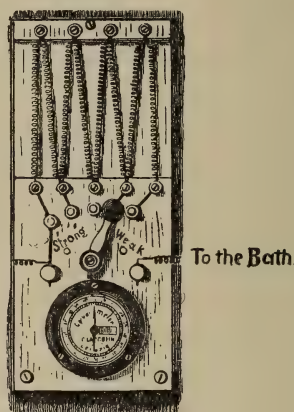


FIG. 52.



Its action is based upon the following conditions: As explained on p. 20, the maximum performance of a battery takes place when the external resistance is equal to the internal resistance of the battery. By increasing the external resistance, the performance is decreased, and a current of less intensity will pass into the bath when resistances are placed in the circuit. The longer and thinner the conducting wire is, and the less conducting power it possesses, the greater will be the resistance which it opposes to the current. Hence, the resistance board consists of metallic spirals which lengthen the circuit, contract it by a smaller cross-section, and by the nature

of the metallic wire has a resistance-producing effect. For a slight reduction of the current, copper spirals of various cross-sections are taken, which are succeeded by brass spirals, and finally by German silver spirals, whose resistance is eleven times greater than that of copper spirals of the same length and cross-section. In Fig. 51 the conducting wire coming from the battery goes to the screw on the left side of the resistance board, which is connected by stout copper wire with the first contact-button on the left; hence by placing the metallic switch upon the button furthest to the left, the current passes the switch without being reduced, and flows off through the conducting wire secured to the setting-screw of the switch. By placing the switch upon the next contact-button to the right, two copper spirals are brought into the circuit; by turning the switch to the next button, four spirals are brought into the circuit, and so on. By a choice of the cross-sections of the spirals, their length and the metal of which they are made, the current may be more or less reduced as desired.

To control the reduction of the current effected by the resistance, a galvanometer is placed behind it. It consists of a magnetic needle oscillating upon a pin, below which the current is conducted through a strip of copper, or, with weaker currents, through several coils of wire. The electric current deflects the magnetic needle from its position, and the more so the stronger the current is; hence the current-strength of the battery can be determined by the greater or smaller deflection.

For a weak current, such as, for instance, that yielded by two elements, it is of advantage to use a horizontal galvanometer (Fig. 53). It is screwed to a table by means of a few brass screws in such a position that the needle in the north position, which it occupies, points to  $0^{\circ}$  when no current passes through the instrument. Articles of iron and steel must, of course, be kept away from the instrument. For stronger currents, it is better to combine a vertical galvanometer

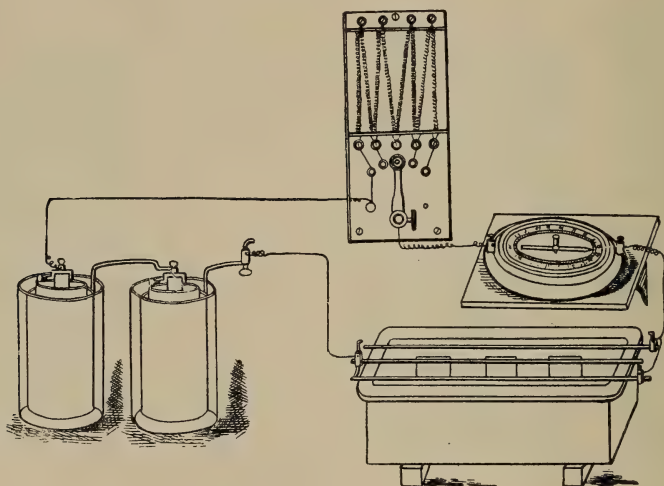
FIG. 53.





with the resistance board and fasten it to the same frame, as shown in Fig. 52. The screw of the handle of the resistance board is connected with one end of the copper strip of the vertical galvanometer, while the other is connected with the screw on the right side of the resistance board in which is secured the wire leading to the bath. The resistance board and galvanometer are placed in one conducting wire only, either in that of the anodes or of the objects; one of these wires is simply cut, and the end connected to the battery is secured in

FIG. 54.

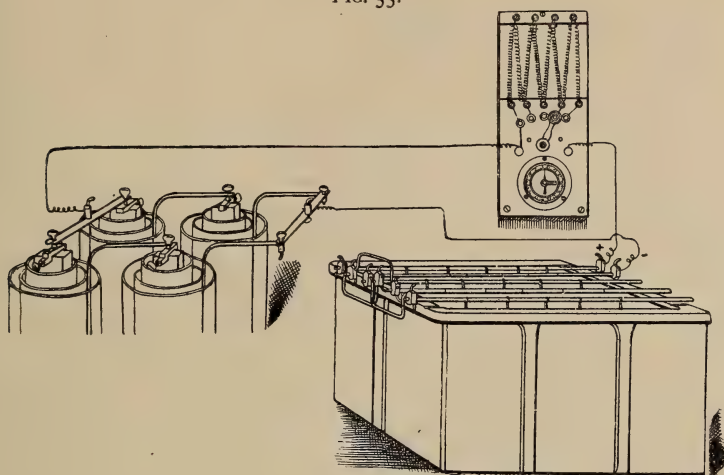


the setting-screw on the side of the resistance board marked "strong," while the other end which is in connection with the bath is secured in the setting-screw on the opposite side marked "weak." The entire arrangement will be perfectly understood from Figs. 54 and 55.

Fig. 56 shows the Improved H. & V. W. Patent Underwriters' switch board or rheostat, which has twice the carrying capacity of any resistance board ever made for this purpose, it having sufficient length of wire to allow of toning down the highest electro-motive force used in plating, to the lowest

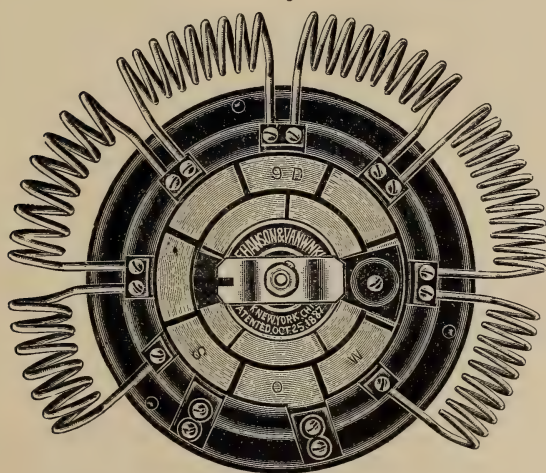
figure called for, without showing heat or any unfavorable symptoms. By the use of this switch board, the output from

FIG. 55.



a plating room using two or more tanks can be doubled, providing the dynamo has the current capacity.

FIG. 56.



All platers understand that different voltages are required to

operate successfully different kinds of solutions, and that when a sufficient voltage is to be generated for a solution of the highest resistance, and at the same time utilized in low resistance solutions, the tank nearest the dynamo, with the customary method, receives the most current, and a tendency to burn and blacken is noticed to a marked degree. When metals such as silver and copper are to be deposited in connection with such metals as nickel and brass, a higher electro-motive force is required, and considerable drop in voltage is demanded in the lower resistance solutions so as not to blacken the work. With the old style switch boards this is done at a great loss of current and work capacity of tank. With the old style switch boards about the greatest carrying capacity that they will feed is from 25 to 35 amperes; not over 35 amperes. This deficiency is due to the smallness of the resistance wire and lack of sufficient metal conductivity. With this switch board, three times the current can be conveyed without showing the least heat in either the resistance wires, segments, switch, or base-plate.

The advantages derived from the use of a resistance-board having been referred to, it remains to add a few words regarding the indications made by the galvanometer. Since the greater deflection of the needle depends, on the one hand, on the greater current-strength, and, on the other, on the slighter resistance of the exterior closed circuit (conducting-wires, baths and anodes), it is evident that a bath with slighter resistance, when worked with the same battery and containing the same area of anodes and objects, will cause the needle to deflect more than a bath of greater resistance under otherwise equal conditions. Hence, the deductions drawn from the position of the needle for the electro-plating process are valid only for definite baths and definite equal conditions, but, with due consideration of these conditions, are of great value. Suppose a nickel bath to work always with the same area of objects and anodes, and experiments have shown that the suitable current-strength for this area of objects is that at which the needle

stands at  $15^{\circ}$ ; and suppose, further, that the battery has been freshly filled and causes the needle to deflect to  $25^{\circ}$ , then the switch of the resistance-board will have to be turned so far to the right that the needle in consequence of the interposed resistances returns to  $15^{\circ}$ . Now if, after working for some time, the battery yields a weaker current, the needle, by reason of the resistance remaining the same, will constantly retrograde, and has to be brought back to  $15^{\circ}$  by turning the switch to the left, when a current of equal strength to the former will again flow into the bath. This manipulation is repeated until finally the switch rests upon the button furthest to the left, at which position the current flows directly into the bath without being influenced by the resistances of the resistance-board. If now the needle retrogrades below  $15^{\circ}$ , it is an indication to the operator that he must renew the filling of the battery if he does not prefer suspending fewer objects in the bath. For this reduced area of objects it is no longer required for the needle to stand at  $15^{\circ}$  in order to warrant a correct progress of the electric process, since the resistance being in this case greater, a deflection to  $10^{\circ}$ , or still less, may suffice. This example will make it sufficiently clear that the current-indication by the galvanometer is not and cannot be absolute, but that the deductions must always be drawn with due consideration to the conditions, namely, area of objects and of anodes, and distance between them. An operator to proceed safely in this respect, and, above all, desiring to work scientifically, will replace the simple galvanometer by a voltmeter, which indicates the absolute magnitude of the electro-motive force passing into the bath, as will be explained later on.

It frequently happens that in consequence of defective contacts with the binding-screws of the battery, or by the conductors of the objects and of the anodes touching one another (short circuit with non-insulated conducting wires), no current whatever flows into the bath. Such an occurrence is immediately indicated by the galvanometer, the needle being not at all deflected in the first case, while in the latter the deflection will



be entirely different from the usual one. The magnetic needle of the galvanometer also furnishes a means of recognizing the polarity of the current. If the galvanometer be placed in the positive conductor by securing the wire coming from the battery in the binding-screw on the south pole of the galvanometer, and the wire leading to the bath in the binding-screw on the north pole of the needle, the needle, according to Ampère's law, will be deflected in the direction of the hands of a watch, *i. e.*, to the right if the observer stands so in front of the galvanometer as to look from the south pole towards the north pole, because the battery current flows out from the positive pole through the conducting wire, anodes, and fluid to the objects, and from these back through the object wire to the negative pole of the battery. If now in consequence of the counter-current formed in the bath by the metallic surfaces of dissimilar nature (see later on), and flowing in an opposite direction to that of the battery-current, the latter is weakened, the needle will constantly further retrograde from the zero point, and when the counter or polarizing current becomes stronger than the battery-current, it will be deflected in an opposite direction as before. Hence, by observing the galvanometer the operator can avoid the annoying consequences of polarization, which will be further discussed under nickeling.

From what has been said in this chapter and in the theoretical part, the rules which have to be observed in conducting the current will be readily understood. Since the current-strength is weakened by resistance, the cross-sections of the current-carrying wire as well as of the wires leading to the objects and to the anodes must be of a size corresponding to the current-strength, and the material selected for the wires should possess the highest conducting power possible. Chemically pure copper is best suited for this purpose. Some information for calculating the thickness of the wires will be found on the end of the section "Arrangement with dynamo machines."

The connection between the anodes of the bath and the

positive pole (anode or carbon pole) of the battery is effected by the *positive* or *anode* wire, while the *negative* or *object wire* brings the objects in the bath into metallic contact with the negative (zinc pole) of the battery. As previously mentioned, the resistance board with galvanometer is placed in one or the other of the wires.

For conducting the electric current to the baths, metallic wires, bands, spirals, or ribbons are used. The conducting wires are either employed in their natural metallic state, or are covered with some insulating or poorly conducting substance, such as cotton, silk, India-rubber, gutta-percha, and various varnishes. It is evident that covered wires should be bare and clean at their extremities where they are connected with the battery and with the anodes and objects to be plated. Wires of pure, well-annealed copper possess the best conducting power, and should have a sectional area capable of carrying the maximum quantity of current without offering appreciable resistance. Cables should be chosen where a large volume of current must be carried, they being more flexible than wire of a large size, and can be more easily laid.

Insulated wires may come in contact with each other without inconvenience. Such, however, is not the case with bare wires; because the electricity will pass through the shortest circuit and will not go through the bath if the two wires are in metallic contact. Such contact should, therefore, be carefully avoided.

*Vats or tanks.*—These are the vessels to hold the plating solutions. Their shape may be either circular, square, or rectangular. They should be perfectly tight, impervious to the solutions, and unacted upon by them. They are made of different materials—stoneware, glass, or porcelain vats being best, but they are the most fragile and expensive.

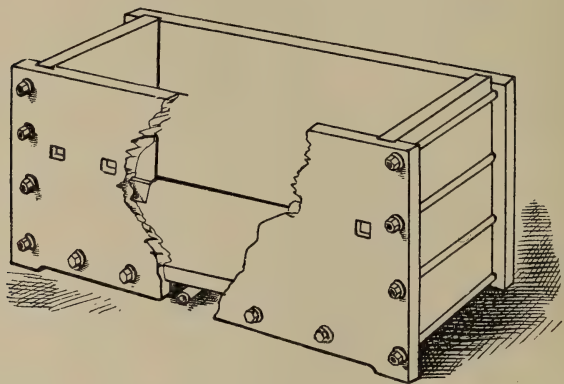
Wooden vats must be carefully constructed, and are best secured at the ends by bolts and nuts, as shown in Fig. 57, which serve to hold the sides firmly against the end pieces.

The vat is then coated with a mixture of equal parts of pitch

and rosin boiled with a small quantity of linseed oil. Another mixture, which has been found to afford a good protective covering to wood, consists of 10 parts of gutta-percha, 3 0 pitch, and  $1\frac{1}{2}$  each of stearine and linseed oil, melted together and incorporated.

For large acid *copper* and *nickel* baths wooden vats lined with chemically pure sheet lead about 0.118 inch thick, and the seams soldered with pure lead, are quite suitable. Care must, of course, be taken that neither the conducting rods nor the articles suspended in the bath and the anodes come in contact with the lead lining, and therefore the conducting rods should

FIG. 57.



not be laid directly upon the vats, but placed upon a few thick strips of dry wood. Further, the anodes should be suspended at a sufficient distance from the lead lining, because with too small a distance metal from the solution is precipitated upon the lead lining. The latter always becomes electric, which, however, does not matter, and if the anodes are at a greater distance from the lead lining than the objects no metal is precipitated upon the lead lining. If for the better exhaustion of the baths the anodes are suspended at a slight distance from the sides, it is advisable to protect the lead lining with thin wooden boards or to insulate it by giving it two coats of asphalt-lacquer.

However, for this purpose asphalt-lacquer prepared from the residues of the tar industry is not available, and a solution of Syrian asphalt, with a small quantity of Venetian turpentine, should be employed.

Objections have frequently been made to such vats, but in Dr. George Langbein's establishment they have for more than ten years been used for nickel baths without the slightest effect upon the baths, and no disturbance in the working of the latter has ever been observed. Based upon careful investigations, such lead-lined vats have even been used for large copper and brass baths containing potassium cyanide without the slightest injury to the baths. If even a film of lead cyanide is formed upon the lead, it is insoluble in excess of potassium cyanide, and hence is entirely indifferent as regards the bath. However, for nickel baths containing large quantities of acetates, citrates and tartrates these lead-lined vats cannot be recommended, since these salts possess a certain power of dissolving lead oxide. Still, the use of such baths has been almost entirely abandoned, and the small quantities of organic acid which occasionally serve for correcting the reaction of a nickel bath need not be taken into consideration. The lead-lining might be dispensed with if it were not for the difficulty of keeping wooden vats tight. Many plating solutions impair the swelling power of the wood, and with even a slight change in the temperature the vats become pervious, the evil in time increasing. Vats lined with lead, on the other hand, remain tight, and have the advantage that the baths can be boiled in them by means of steam introduced through a lead coil in the vats.

For large baths containing potassium cyanide holders of brick laid in cement may also be used, or holders of boiler-plate lined with a layer of cement.

A very useful vat is one of iron enameled with white acid-proof enamel. Such vats are made in different shapes and sizes up to  $5\frac{1}{2}$  feet long, 24 inches wide and 19 inches deep.

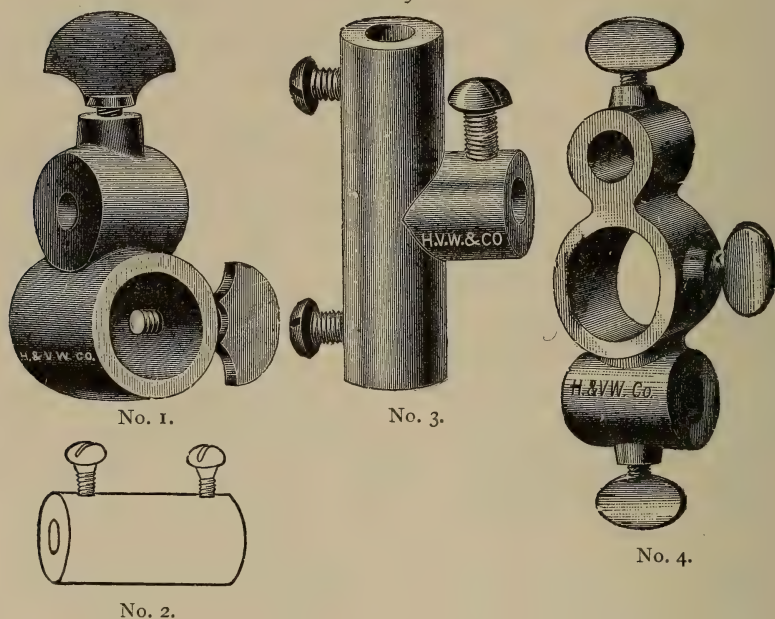
For gold and other solutions an agate vessel is recommended, this material standing cyanide solutions, acids, etc.



The vats for heating baths are best made of enameled iron or of wood lined with sheet lead. Stoneware vats do not bear heating.

It is advantageous to provide the narrow sides of the vats with semicircular notches for the conducting rods to rest in, to prevent their rolling away. When using stoneware vats the conducting rods are laid directly upon the vats. Vats of other material must be provided with an insulated rim of wood, or

FIG. 58.



the rods are insulated by pushing pieces of rubber tubing over their ends. According to the size of the bath, 3, 5, 7, or more conducting rods, best of pure massive copper, or if this is too expensive, of strong brass tubing with iron rods inside, are used.

To secure the uniform coating of the objects with metal they must be surrounded as much as possible by anodes, *i. e.*, the positive pole plates of the metal which is to be deposited. For

flat objects it suffices to suspend them between two parallel rows of anodes, the most common arrangement being to place three rods across the bath, the two outermost of which carry the anodes, while the objects are secured to the centre rod. For wide baths five conducting rods are frequently used, but they should always be so arranged that a row of objects is between two rows of anodes. The arrangement frequently seen with four rods across the baths, of which the outermost carry anodes, and the other two, objects, is irrational if the objects are to be uniformly plated on all sides; because, the sides turned towards the anodes are coated more heavily than those suspended opposite to the other row of objects.

For large round objects it is better to entirely surround them with anodes, if it be not preferred to turn them frequently, so that all sides and portions gradually feel the effect of the immediate neighborhood of the anodes. (See "Nickeling.")

For objects to be plated on one side only the centre rod may be used for the anodes, and the two outer ones for the objects; the surface to be plated being, of course, turned towards the anodes.

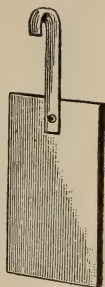
The rods carrying the anodes, as well as those carrying the objects, must be well connected with each other, which is effected by means of binding posts and screws of the improved forms shown in Fig. 58, Nos. 1 and 2 being rod connections for tanks. No. 2, or double connection, is a very convenient form, as it can be adapted to so very many changes. The three-way connection, No. 3, is so well known that it hardly needs an explanation.

The anodes are suspended from the cross rods by strong hooks of the same metal, so that they can be entirely immersed in the bath (Fig. 59). Hooks of another soluble metal would contaminate the bath by dissolving in it, and this must be strictly avoided,

FIG. 59.



FIG. 60.



as it would cause all sorts of disturbances in the correct working of the bath. In case hooks of another metal, except platinum, are used, the anodes must be hung so that they project above the surface of the liquid, and the hooks not being immersed are, therefore, not liable to corrosion; but the anodes are then not completely used up, the portion dipping in the solution being gradually dissolved, whilst the portion projecting above the fluid remains intact. Instead of wire hooks, strips of the same metal as the anodes and fastened to them by a rivet may also be used (Fig. 60).

For suspending the objects, lengths of soft pure copper wire, technically called *slinging wires*, are used. They are simply suitable lengths of copper wire of a gauge to suit the work in hand, wire of No. 20 Birmingham wire gauge (see Appendix, "Useful Tables,") being generally employed for such light work as spoons, forks and table utensils. Wire of a larger diameter should be employed for large and heavy goods. The immersed ends of these wires becoming coated with the metal which is being deposited, they should be carefully set aside each time after use, and when the deposit gets thick it should be stripped off in stripping acid, and the wire afterwards annealed and straightened for future use.

To keep the rods clean and to protect them from the fluid draining off from the articles when taken from the bath, it is advisable to cover them with a roof of strips of wood ( $\wedge$ ), or a semi-circular strip of zinc coated with ebonite lacquer; by this means the frequent scouring of the rods, which otherwise is necessary in order to secure a good contact with the hooks of the anodes, is done away with.

The plating solutions, briefly called baths, will be especially discussed in speaking of the various electro-plating processes. It still remains to consider the cleansing and rinsing apparatuses. Every electro-plating establishment, no matter how small, requires at least one tub or vat in which the objects can be rubbed or brushed with a suitable agent in order to free them from grease. This is generally done by placing a small kettle or

stoneware pot containing the cleansing material at the right-hand side of the operator alongside the vat or tub. Across the latter, which is half filled with water, is laid a board of soft wood covered with cloth, which serves as a rest for the objects previously tied to wires. The objects are then scrubbed with a brush, or rubbed with a piece of cloth dipped in the cleansing agent. The latter is then removed by rinsing the objects in the water in the tub and drawing them through water in another tub. By this cleansing process a thin film of oxide is formed upon the metals, which would be an impediment to the intimate union of the electro-deposit with the basis-metal. This film of oxide has to be removed by *dipping* or *pickling*, for which purpose another vat or tub containing the *pickle*, the composition of which varies according to the nature of the metal, has to be provided. After dipping, the objects have to be again thoroughly rinsed in water to free them from adhering pickle, so that for the preparatory cleansing processes three vessels with water, which has to be frequently renewed, as well as the necessary pots for pickling solutions, have to be provided. In case the vat for cleansing the articles or the box-like table (see Fig. 69) is provided with a rose-jet, under which the objects are rinsed, the other vats are not required.

After having received the electro-deposit, the objects have to be again rinsed in cold water, which can be done in one of the three vats or with the rose-jet, and finally have to be immersed in hot water until they have acquired the temperature of the latter. How the water is heated makes no difference, and depends on the size of the establishment. The heated objects are then immediately dried in a box filled with dry, fine sawdust—that of maple, poplar, or other wood free from tannin being suitable for the purpose.

*B. Arrangement with dynamo-electric machines.*—For setting up and running a dynamo the following rules are to be observed. It is important that the dynamo be properly placed and the following considerations should govern the choice of location. The dynamo should not be exposed to moisture nor



to the dust and dirt of the polishing room. Cleanliness is a necessity. A cool, well-ventilated room should be chosen. This is important, for a well-ventilated machine will do more work with less wear on parts than one unfavorably placed.

Dynamos should be set on substantial foundations, as absence of vibration adds to the life of machines, and insures a more uniform current. For the larger sizes a solid masonry foundation should be used, while a frame work of timber will answer all the requirements of the smaller sizes. When the dynamo is placed upon the foundation it should be carefully leveled and accurately lined up with the driving shaft and pulley of countershaft.

The *commutator* is an important part and requires careful attention. Its surface should be kept smooth. If it should become roughened use No. 00 sand paper, which can be applied while the commutator is revolving. *Never use emery cloth.* As a rule the commutator only requires to be wiped off with a piece of canvas. The part should be lubricated, using a small quantity of oil, applied with a piece of cloth, not waste. When the commutator is out of true, it should be turned in a lathe.

The *brushes* should be set so that the points of contact on the commutator at the top and bottom are diametrically opposite, care being taken that the brushes bear evenly on the commutator for their full surface. A brush resting on corner or edge will cause sparking and cutting. After adjusting the brushes and obtaining proper tension, start the dynamo and shift the brushes on the commutator to a point where there is no sign of sparking. This position can always be found by loosening the rocker-arm and moving it to the proper point, when the screw in the rocker-arm should be tightened to hold the latter in position.

*Sparking* may be caused if the brushes are not set at the point of commutation as above directed. Brushes should not be fitted to the circumference of the commutator. It is important that the full surface of the brush should bear on the commutator.

Dynamos should be run at a speed designated on the name plate, care being taken that there is no slippage of belts to the dynamo or from the main line to the countershaft. If it is necessary to change the speed, never change the pulley on the machine; make the alteration elsewhere.

Fill the bearings of the dynamo with good lubricating oil until it just overflows at the shaft. When properly filled it will run for weeks without further attention.

Use a good quality of thin, pliable belting. If possible, place the dynamo in such a position that a slanting belt can be used, and so that the underside of the belt does the pulling.

The armature should be frequently cleaned from copper-dust by means of a small bellows or other instrument. Movable articles of iron and steel should be kept away from the machine when running, as they might be attracted by the portions of the machine which have become strongly magnetic.

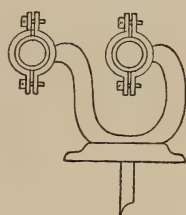
The object- and anode-wires must be insulated from each other, as well as from the ground and damp brick-work by dry wood or porcelain, and the places of junction kept bright.

The employment of special wire-carriers, of the form shown in Fig. 61, is advisable. They consist of cast-iron arms, provided on the ends with a case, between the lower and upper cover of which are disks of hard rubber.

For the regulation of the current, resistance boards or rheostats are used. They are constructed according to the same principles as those described under "Arrangements with Elements" (p. 97), only the spirals are longer and of a larger cross-section, and the entire instrument is stronger. Instead of upon wood the contact-buttons are mounted upon slate plates, as wood would be carbonized by the spirals becoming hot.

In case one machine has to feed several baths of dissimilar nature and composition, the regulation of the current for all the baths in the main conducting wire is not feasible on ac-

FIG. 61.



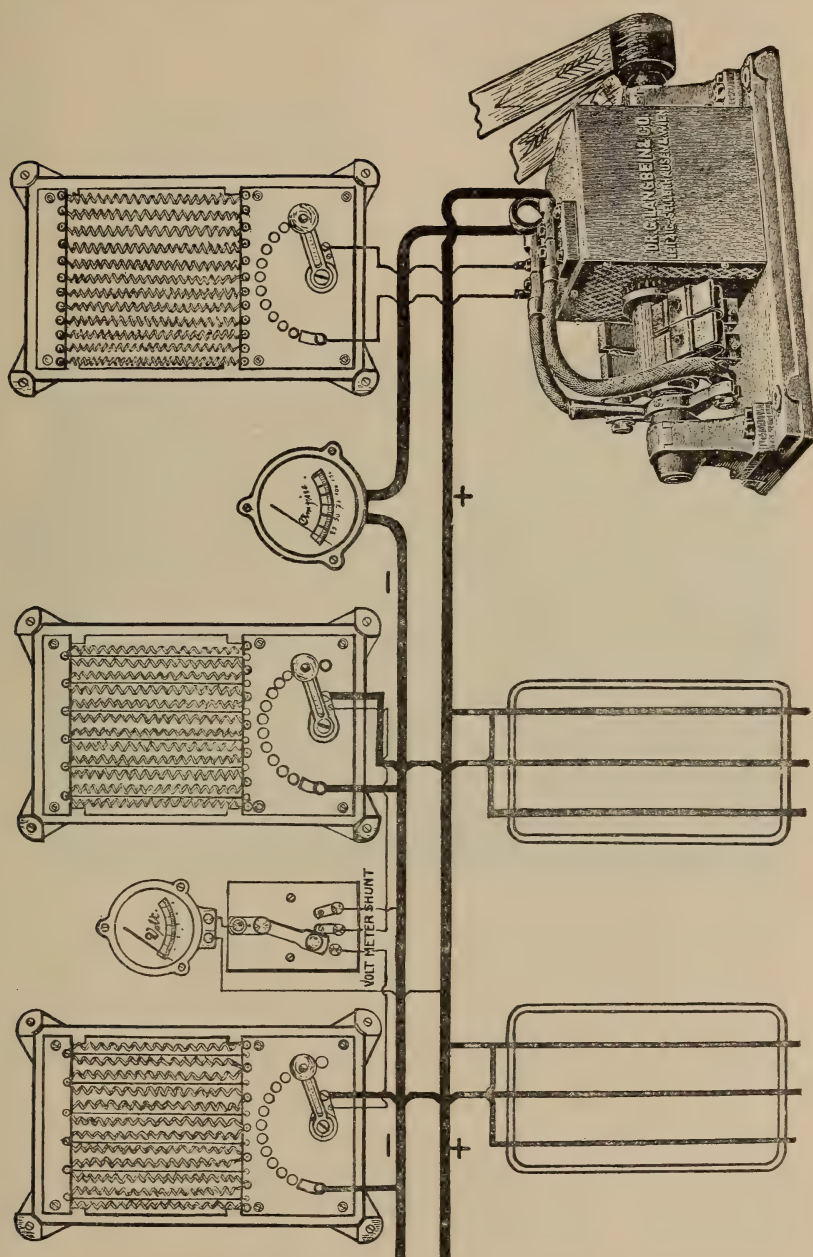
count of the different resistances, and it will be necessary to place a rheostat in front of every tank. With the use of a shunt-wound dynamo of the Langbein or Lahmeyer type it will be further necessary to place a rheostat (the rheostat of the dynamo) in the field of the machine itself, in order to be enabled to generate more or less current, as may be required, and to avoid an unnecessary consumption of power. From the scheme Fig. 62 of such a machine, with the auxiliary apparatus, the main conducting wire, and a few baths, the reader will readily see what is required.

The dynamo rheostat will have to be placed so that the machine yields somewhat more current than with due consideration to the object area is required for all the baths, while the supply of current for each vat is regulated by the rheostat placed in front of it.

In the scheme Fig. 62 are sketched two additional instruments for measuring the quantity and the electro-motive force of the current. By the first called the *ampèremeter*, or better *ammeter*, the whole current-strength can be directly read off in ampères, and by the other, called the *voltmeter*, the electro-motive force or tension in volts.

The observing practical electro-plater will know that the character of a deposit obtained in a certain solution with a definite area of objects to be plated depends largely upon the reproduction of certain conditions, and especially upon the density of the current for the certain area to be plated. To reproduce such conditions it is highly important that either the electro motive force existing between anode and cathode, or the current flowing through the same, be accurately measured. The ordinary galvanometer is insufficient and often misleading, and not at all satisfactory for the actual measurement of either the voltage or current. It indicates only a change of polarity, a cause of trouble not often occurring with the use of a good dynamo. If it is desired to measure the actual E. M. F. existing at the terminal of the dynamo or bath, only the very best voltmeters or ammeters should be used. They should be so

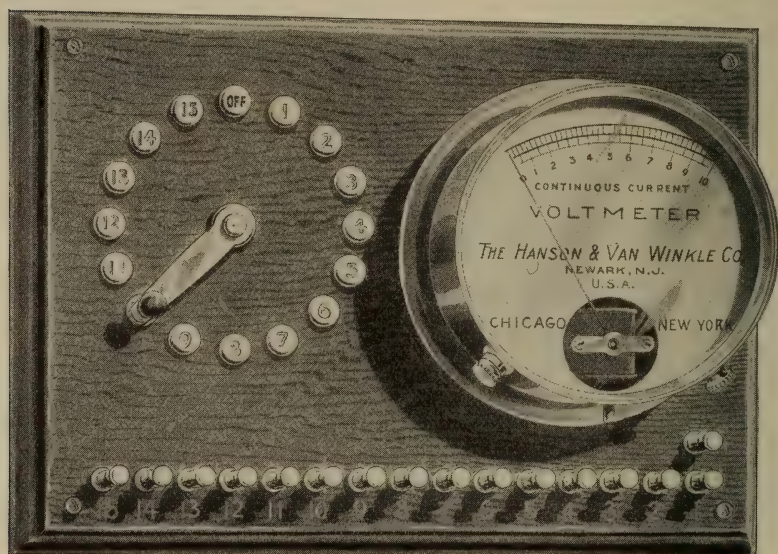
FIG. 62.





constructed as to indicate quickly and accurately any sudden changes in current, and should be direct reading in volts and ampères, and their indications should not be subjected to gradual changes. A sensitive voltmeter, such as the Starrett improved voltmeter, shown in Fig. 63, will indicate the slipping of belts, short circuiting in tanks and any irregularity of power. These voltmeters have a scale from 0 to 6 volts and upwards. The scale is divided into 120 divisions so that each

FIG. 63.



division represents  $\frac{5}{100}$  of a volt and when used in connection with the switch board, will enable the plater to study carefully all the requirements that insure good results, and will give him the means of accurately reproducing such conditions as he has found by experience conducive to success. One voltmeter can be made to answer for a number of tanks by means of a shunt from which the wires run to each tank. By this arrangement, and in connection with the switch-boards, the voltage for each tank and the current passing through the tank are controlled.

Fig. 64 shows the little H. & V. W. voltmeter. These instruments may be connected to each tank by hanging overhead or by screwing on the back of the tank, an advantage to the plater who is operating solutions that require different voltages. By touching the button the tension of current at each tank can be instantly determined. The instrument is calibrated with a standard voltmeter

FIG. 64.

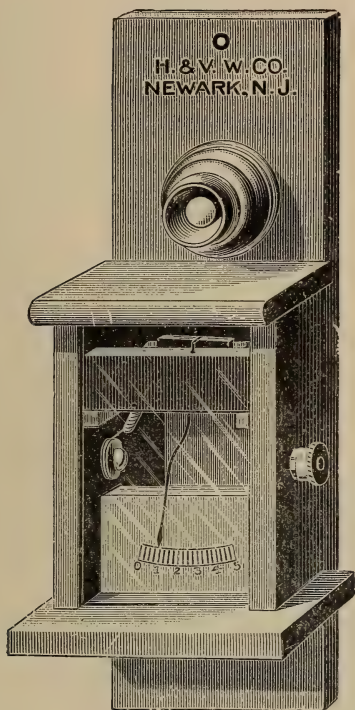
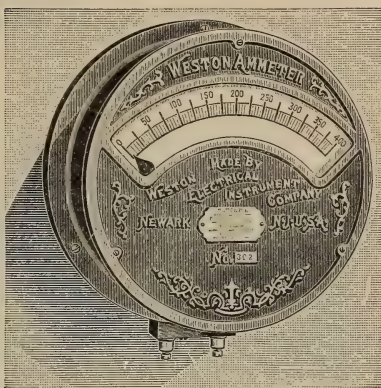


FIG. 65.



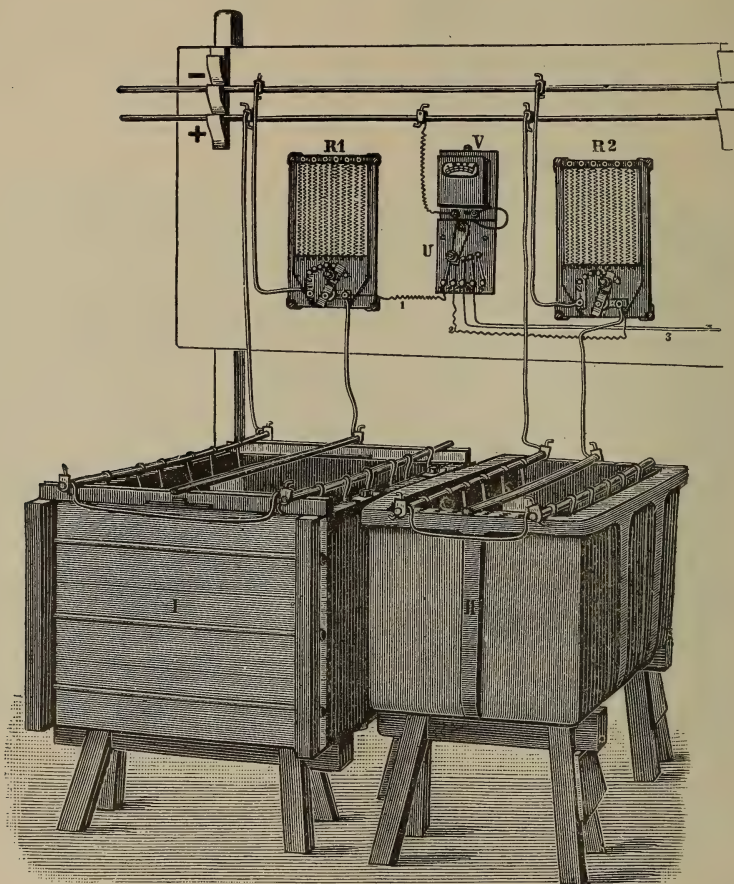
and is reliable. It cannot be left in circuit, and for this reason a switch is provided.

The Weston voltmeter is also largely used. It is of the same general appearance as the Weston ammeter, Fig. 65.

Whilst it will be sufficient in most cases to use a voltmeter in combination with a rheostat for regulating purposes, it will sometimes be found desirable to determine the actual amount of current in ampères passing through a tank. It is a fundamental law of electrolysis that a certain number of ampères passing through a plating solution will cause a definite weight of metal to be deposited. So, for instance, one ampère will

deposit in one hour 1.106 grammes of nickel, or 4.05 grammes of silver. It is evident, therefore, that by means of an accurate ammeter, the amount of metal actually deposited can easily be

FIG. 66.



determined. The Weston ammeter, shown in Fig. 65, is very sensitive, indicating the slightest variation of current accurately and with absolute certainty. It is, especially for higher ranges, the best, the most economical, and at the same time the

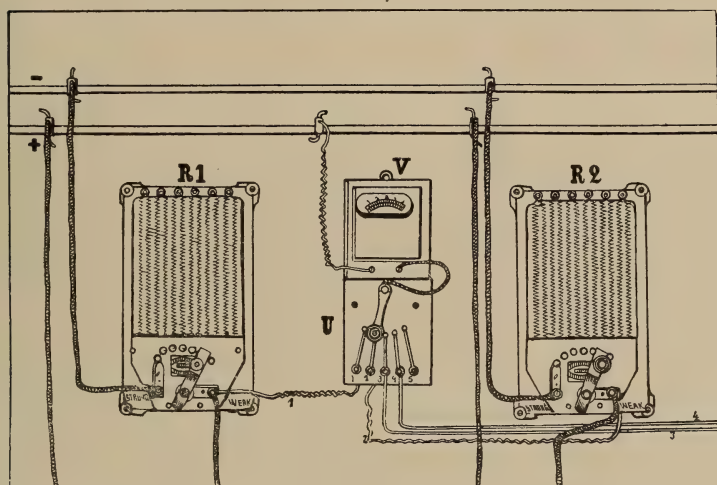


cheapest instrument in the market. Both the Weston voltmeter and the Weston ammeter are furnished by Hanson & Van Winkle Co., Newark, N. J.

As previously mentioned, one voltmeter can be made to answer for a number of tanks by means of a switch, from which the wires run to each tank, the arrangement being shown in Figs. 66 and 67.

Fig. 66 shows the coupling of the main object-wire (—) and the main anode-wire (+) with the resistance-boards  $R_1$  and  $R_2$ , the voltmeter  $V$ , the switch  $U$ , and the two baths.

FIG. 67.



In Fig. 67 the coupling is enlarged, and upon this the following description is based: Suppose the main object-wire and anode-wire to be connected with the corresponding poles of a dynamo-machine or a battery, which for the sake of a clearer view is omitted in the illustration. The switch  $U$  consists of a brass handle, mounted with a brass foot, upon a board. In the foot is a screw, with which is connected by a 0.039-inch thick copper-wire one of the pole-screws of the voltmeter. The switch drags with spring pressure upon contact buttons connected by copper wire with the setting screws 1, 2, 3, 4, 5



(upon the switch-board), which serve for the reception of the 0.039-inch thick insulated wires 1, 2, 3, 4, for measuring the tension, which branch off from the various vats or resistance-boards. The other pole-screw of the voltmeter is directly connected with the main anode-wire. From the main object-wire, a wire, whose cross-section depends on the strength of the working current, passes to the screw marked "strong" of the resistance-board  $R_1$ ; the screw marked "weak" of the resistance-board  $R_1$  is connected by a correspondingly stout wire with the object-wire of bath I, and at the same time with the binding-screw 1 of the shunt. The resistance-board  $R_2$ , of the bath II, is in the same manner connected with the main object-wire, the bath, and the binding-screw 2 of the switch; also the resistance-boards  $R_3$  and  $R_4$  of the baths III and IV, which are not shown in the illustration. With the main anode-wire each bath is directly connected by conducting the current to an anode-rod of the bath by means of binding-screws and a stout copper wire, and establishing a metallic connection between this anode-rod and the next one. However, instead of connecting both, the current may also be conducted from the main anode-wire to each anode-rod.

In the illustration, the handle of the switch rests upon the second contact-button to the left, which is connected with the binding-screw 2 of the board. In the latter is secured the wire for measuring the tension of the resistance board  $R_2$ ; and hence the voltmeter  $V$  will indicate the tension of the current in bath II. Suppose bath II is full of objects, and with the position of the switch of the resistance board at "weak," as shown in the illustration, the voltmeter indicates 1.5 volts, while the most suitable tension for the bath is 2.5 volts, the switch of the resistance board is turned to the left until the needle of the voltmeter indicates the desired 2.5 volts.

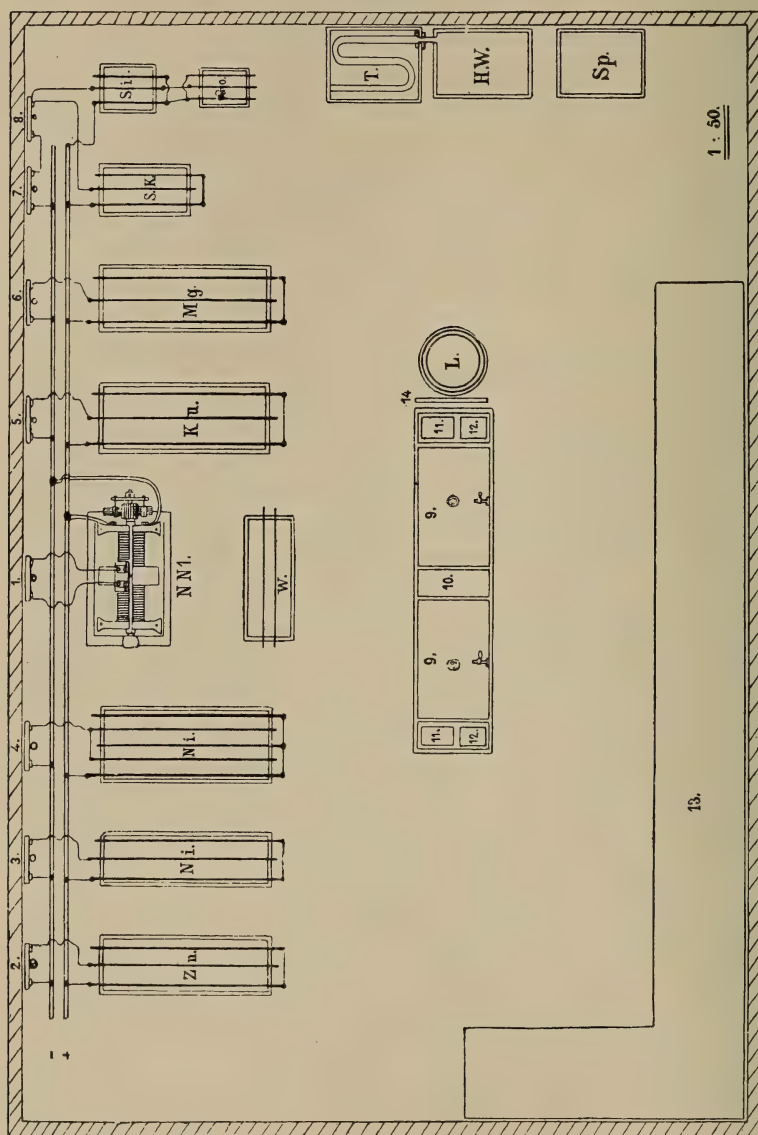
By turning the switch of  $U$  to the left, so that it rests upon the contact-button 1, the measuring wire of bath II is thrown out, and the voltmeter indicates the tension in bath I. If the switch rests upon contact-button 3, the tension in bath III is indicated, and so on.

The various baths of a larger electro-plating establishment are most suitably worked in parallel coupling, *i. e.*, each bath is directly fed from the main wire after the current has been brought to the proper degree by the resistance board. Coupling the baths one after the other whereby the current passes from one bath into the other is only practicable for metallurgical purposes (gaining of metals), the baths in this case having the same resistance, and in each bath the same areas of objects and anodes are suspended, so that one bath works under the same conditions as the other. But it is far otherwise in electro-plating establishments in which nickel, copper, brass, silver, gold and other baths are operated whose resistances are entirely different.

Fig. 68 shows the ground plan of an electro-plating establishment.  $NN^1$  is a dynamo-electric machine, with 300 ampères at 4 volts' tension. The resistance board belonging to the machine, which is placed in the conductor, is indicated by No. 1, and is screwed to the wall. The main conductors, marked — and +, run along the wall, from which they are separated by wood, and consist of rods of pure copper 0.59 inch in diameter. The rods are connected with each other by brass coupling-boxes with screws. From the negative pole and the positive pole of the machine to the object-wire and anode wire lead two wires, each 0.27 inch in diameter; one end of each is bent to a flat loop and secured under the pole screws of the machine, while the other ends are screwed into the second bore of the binding-screws screwed upon each conductor. To the right and left of the machine the baths are placed;  $Zn$ , indicating zinc bath;  $Ni\ Ni$ , nickel baths,  $Ku$ , copper cyanide bath;  $Mg$ , brass bath;  $SK$ , acid copper bath;  $Si$ , silver bath; and  $Go$ , gold bath. Each of the first-named five baths has its own resistance board, designated by 2, 3, 4, 5, 6. However, before reaching the acid copper bath, and the silver and gold baths, the current is conducted through two resistance boards, 7 and 8. Since these baths require a current of only slight electro-motive force, it is necessary to place two, and in many cases even three or four resistance boards, one

after another, unless it be preferred to feed these baths with a special machine of less tension.

FIG. 68.



From Fig. 68 it will be seen that the current weakened by the resistance boards 7 and 8 serves for conjointly feeding the acid-copper, silver, and gold baths. Hence, practically, only one bath can be allowed to work at one time, as otherwise each bath would have to be provided with as many resistance boards as would be required for the reduction of the tension. For want of space the gold bath is placed in the sketch behind the silver bath; but as their resistance is not the same, they must also be placed parallel.

The coupling of the voltmeter and shunt is omitted in the illustration. Their arrangement will be understood from Fig. 66.

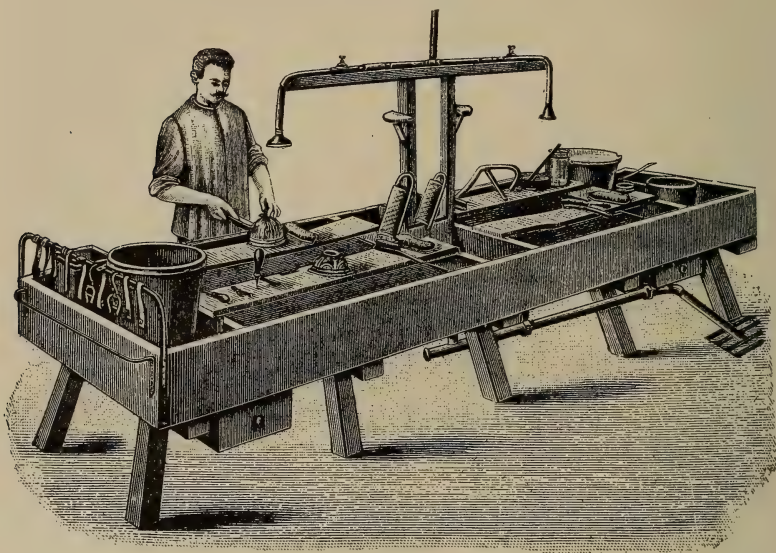
*L* is the lye-kettle. It serves for cleansing the objects, by means of hot caustic potash or soda-lye, from grinding and polishing dirt and oil. Instead of the preparatory cleansing with hot lye, which saponifies the oils, the objects may be brushed off with benzine, oil of turpentine, or petroleum, the principal thing being the removal of the greater portion of the grease and dirt, so that the final cleansing, which is effected with lime paste, may not require too much time and labor. It is also advisable to cleanse the objects, in one way or the other, immediately after grinding, as the dirt, which forms a sort of solid crust with the oil, is difficult to soften and to remove when once hard.

A table for freeing the articles from grease, Fig. 69, stands alongside the lye kettle. It consists of a box standing upon legs and is divided by four partitions into two larger and three smaller compartments. Boards covered with cloth are laid over the larger compartments upon which the objects are brushed with lime-paste for the final thorough freeing from grease. Over each of these compartments is a rose provided with a cock, under which the objects are rinsed with water. The outlets for the waste water from the large compartments are in the bottom of the box and are provided with valves. Of the smaller compartments, the one in the centre serves for the reception of the lime paste (see "Chemical Treatment"),



while the others contain each two pots or small stoneware vats with pickling fluid. In Fig. 68 these vats are indicated by 11 and 12. The two marked 11 contain dilute sulphuric acid for pickling iron and steel articles, while those marked 12 contain dilute potassium cyanide solution for pickling copper and its alloys, and Britannia, etc. For cleansing smaller articles, four men can at one time work on such a table; but for cleansing larger articles only two. For an establishment which does not

FIG. 69.



require such a large table, one with a larger and two smaller compartments may be used. The advantages of such a box-table are that everything is handy together; that the pickle, in case a pot should break, cannot run over the floor of the workshop; and that the latter is not ruined by pickle dropping from the objects. The small box on the side of the table serves for the reception of the various scratch-brushes.

Referring again to Fig. 68, between the lye-kettle L and the box-table, is a frame, 14, for the reception of brass and copper

wire hooks of various sizes and shapes suitable for suspending the objects in the baths.

The reservoir *W*, filled with water, standing in front of the machine, serves for the reception of the cleansed and pickled objects, if for some reason or another they cannot be immediately brought into the bath.

*H W* is the hot water reservoir in which the plated objects are heated to the temperature of the hot water, so that they may quickly dry in the subsequent rubbing in the saw-dust box *Sp*. Before polishing the deposits, iron and steel objects are thoroughly dried in the drying chamber *T* (Fig. 68), heated either by steam or direct fire. By finally adding to the appliances a large table, 13, for sorting and tying the objects on the copper wires, and a few shelves not shown in the illustration, everything necessary for operating without disturbance will have been provided.

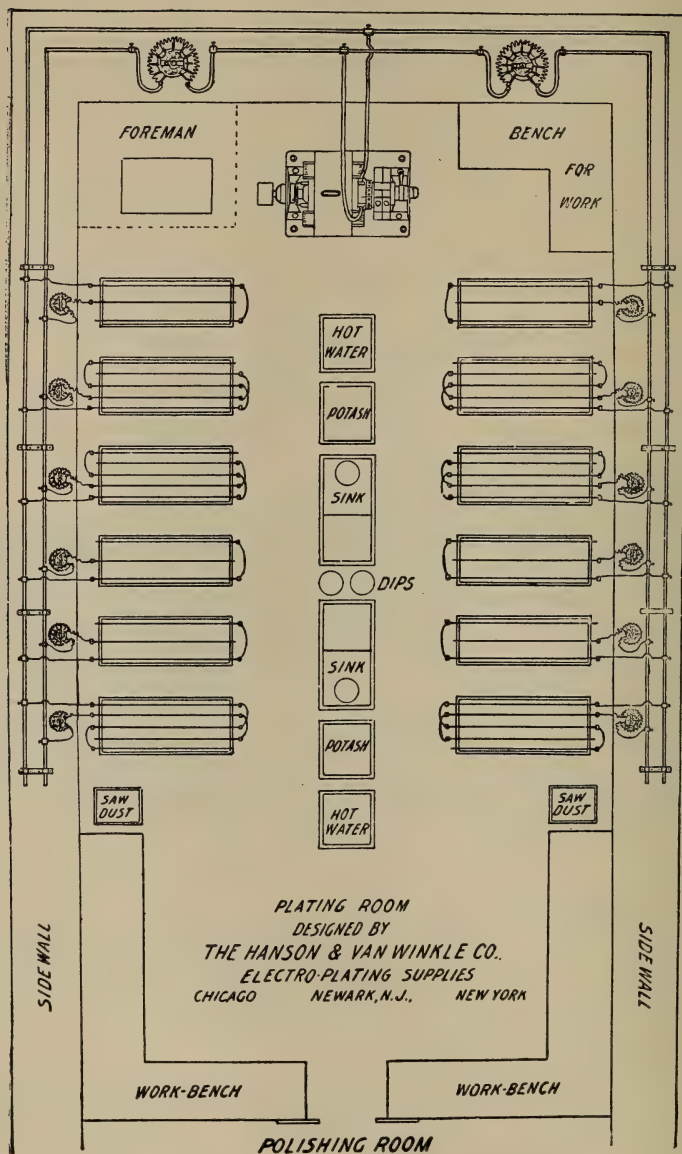
If possible the plating-room should be on the ground floor and where it will receive the best light and ventilation, both being essential to good work. The room must also be provided with facilities for obtaining water and steam, as much of the work in plating is in preparing the article for plating by scouring and rinsing, and, with convenient facilities in doing this, the cost is reduced and better work accomplished. Where a plating plant is required, provision should be made for extension or development of trade. The dynamo should also be larger than absolutely necessary, as a plant can then be enlarged as required by adding one or more tanks, the other appliances remaining the same.

Fig. 70 shows a plating-room arranged by the Hanson & Van Winkle Co., of Newark, N. J. The arrangement will be readily understood from the illustration, so that a detailed description is not necessary.

What has been said in the preceding section in regard to the conducting wires, vats, conducting rods, anodes, etc., also applies to establishments using electro-dynamo machines.

In calculating the thickness of the conducting wires for dyna-

FIG. 70.



mos, 1 square millimetre (0.001 square inch) of conducting cross-section is to be allowed for every 3 ampères for so-called short circuits up to 20 metres (21.87 yards). This is valid for currents up to 500 ampères; for longer circuits  $1\frac{1}{2}$  to 2 ampères are calculated for the square millimetre of conducting cross-section.



## CHAPTER V.

### TREATMENT OF METALLIC ARTICLES.

THE objects having to undergo both a *mechanical* and *chemical* preparation, each of them will be considered separately.

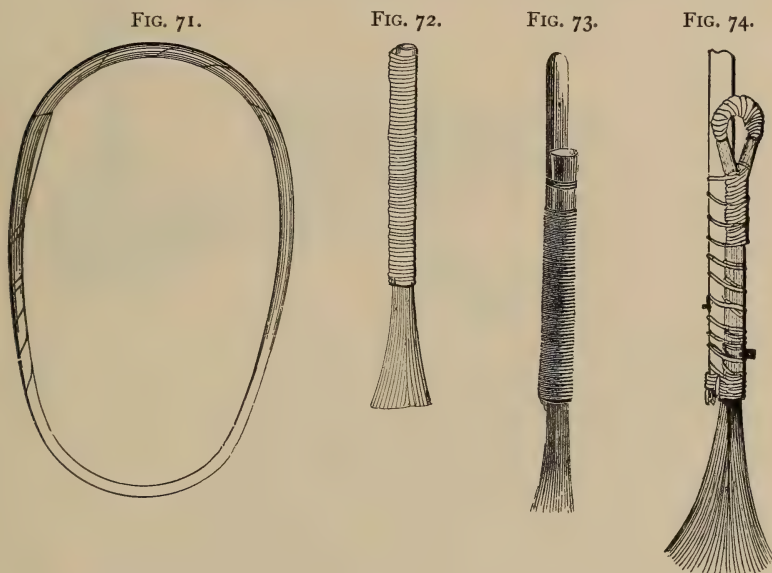
#### A. *Mechanical Treatment.*

1. *Before electro-plating.*—If the objects are not to be electro-plated while in a crude state, which is but rarely feasible, the mechanical treatment consists in imparting to them a *cleaner surface by scratch-brushing*, or a *smoother and more lustrous* one by *grinding* and *polishing*. It may here be explicitly stated that scratch-brushing of electro-plated objects is not to be considered a part of their preparation, since such scratch-brushing is executed in the midst of, or after the electro-plating, process, its object being to effect an alteration of the electro-deposits in more than one direction, and not the cleansing of the surface of the metallic base. The following directions, therefore, apply only to scratch-brushing of objects not yet electro-plated. The scratch-brushing of electro-deposits will be considered later on. In regard to grinding, we have to deal with the subject only in so far as it relates to smoothing rough surfaces by the use of grinding powders possessing greater hardness than the metal to be ground. With grinding in the sense of instrument-grinding, the primary object of which is to provide the instrument with a cutting edge, we have nothing to do.

As some platers seem to have wrong ideas regarding the electro-plating process, it may here be mentioned that the deposit is formed exactly in correspondence with the surface of the basis-metal. If the latter has been made perfectly smooth

by grinding and polishing, the deposit will be of the same nature; but if the basis-surface is rough, the deposits also will be rough. Hence it is wrong to suppose that by electro-plating a rough surface can be converted into a lustrous one, and that pores or holes in the basis-metal can be filled by plating. In order to obtain a deposit which is to acquire high lustre by polishing, it is absolutely necessary to bring the basis into a polished state by mechanical treatment. In doing this it is not necessary to go so far as to produce high lustre, but fine scratches, which would be an impediment to attaining high lustre after plating, must be removed.

*Scratch-brushing* may be effected either by hand or by a



scratch-brush lathe. For hand work scratch brushes of more or less hard brass or steel wire, according to the hardness of the metal to be manipulated, are used. Various forms of brushes are employed, the most common ones being shown in the accompanying illustrations (Figs. 71 to 79).

Fig. 78 shows a swing brush for frosting or satin finish, with

four knots of medium brass or steel wire, and Fig. 79 the plater's lathe goblet scratch-brush.

In scratch brushing it is recommended first to remove, or at least to soften, the uppermost hard and dirty crust (the scale) by immersing the objects in a pickle, the nature of which depends on the variety of metal, so that a complete removal of

FIG. 75.



FIG. 76.

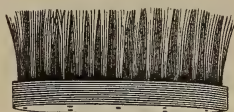


FIG. 77.

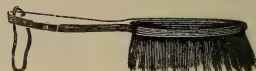
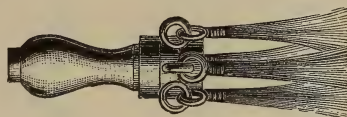


FIG. 79.

FIG. 78.



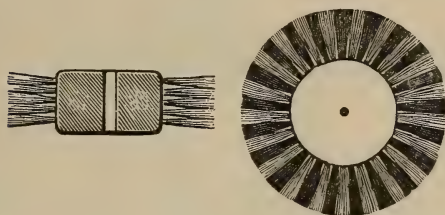
all impurities and non-metallic substances may be effected by means of the scratch-brush in conjunction with sand, pumice-stone, powder, or emery. The composition of pickles will be given later on. Scratch-brushing is complete only when the article shows a clean metallic surface, otherwise the brushing (scouring) must be continued. Scratch-brushes must be carefully handled and looked after, and their wires kept in good order. When they become bent they have to be straightened, which is most readily effected by several times drawing the brush, held in a slanting position, over a sharp grater such as is used in the kitchen. By this means the wires become disentangled and straightened out.

Hand scratch-brushing being slow and tedious work, large establishments use circular scratch-brushes which are attached

to the spindle of a lathe. These circular brushes consist of round wooden cases in which, according to requirement, 1 to 6 or more rows of wire bundles (see Fig. 80) are inserted.

Brushes with wooden cases are, however, more suitable for scratch-brushing deposits than for cleansing the metallic base, since for the latter purpose a more energetic pressure is usually applied, in consequence of which the bundles bend and even break off, if the wire is anyways brittle. For cleansing purposes a circular scratch-brush, which the workman can readily re-furnish with new bundles of wire, deserves the preference. It is constructed as follows: A round iron disk about 0.11 inch thick, and from  $5\frac{3}{4}$  to  $7\frac{3}{4}$  inches in diameter, is provided in the centre with a hole so that it can be conveniently placed upon the spindle of the lathe. At a distance of from 0.19 to 0.31

FIG. 80.



inch from the periphery of the disk, holes 0.079 to 0.11 inch in diameter are drilled, so that between each two holes is a distance of 0.15 inch. Draw through these holes bundles of wire about 3.93 inches long, so that they project an equal distance on both sides. Then bend the bundles towards the periphery, and on each side of the iron disk place a wooden disk 0.31 to 0.39 inch thick. The periphery of the wooden disk, on the side next to the iron disk, should be turned semi-annular, so that the wooden disks when secured to the spindle press very lightly upon the wire bundles, and the latter remain very mobile. When a circular scratch-brush constructed in this manner and secured to the lathe is allowed to make from 1800 to 2000 revolutions per minute, the bundles of wire, in consequence of



the centrifugal force, stand very rigid, but being mobile will give way under too strong a pressure without breaking off, and can thus be utilized to the utmost. When required, the iron disk can be refurnished with wires in less than half an hour. An error frequently committed is that the objects to be cleansed are pressed with too heavy a pressure against the wire brushes. This is useless, since only the sharp points of the wire are effective, the lateral surfaces of the bundles removing next to nothing from the articles.

*Brushes.*—A definition of these instruments is unnecessary, and we shall simply indicate the various kinds suitable to the different operations.

The fire-gilder employs, for equalizing the coating of amalgam, a long-handled brush, the bristles of which are long and

FIG. 81.



FIG. 82.

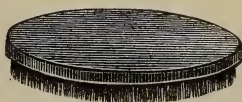


FIG. 83.



very stiff. The electro-gilder uses a brush (Fig. 81) with long and flexible bristles.

For scouring with sand and pumice-stone alloys containing nickel, such as German silver, which are difficult to cleanse in acids, the preceding brush, with smaller and stiffer bristles, is used.

The gilder of watch-works has an oval brush (Fig. 82), with stiff and short bristles for graining the silver.

The galvanoplastic operator, for coating moulds with black-lead, besides a number of pencils, uses also three kinds of brushes—the watchmaker's (Fig. 83), a hat brush, and a blacking-brush. The bronzer uses all kinds of brushes.

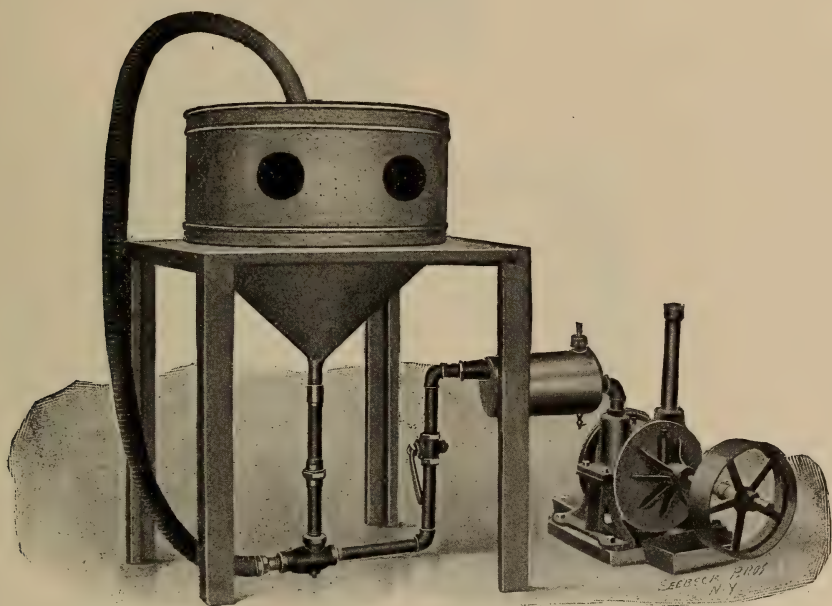
Brushes are perfectly freed from adherent grease by washing with benzine or bisulphide of carbon.

In large establishments engaged in electro-plating cast-iron without previous grinding, the use of the sand-blast in place of

the circular wire brush has been introduced with great advantage. Objects with deep depressions, which cannot be reached with the scratch-brush, as well as small objects, which cannot be conveniently held in the hand and pressed against the revolving scratch-brush can be brought by the sand-blast into a state of sufficient metallic purity for the electro-plating process.

Fig. 84 shows the La Pierre patent sand-blast. This appa-

FIG. 84.

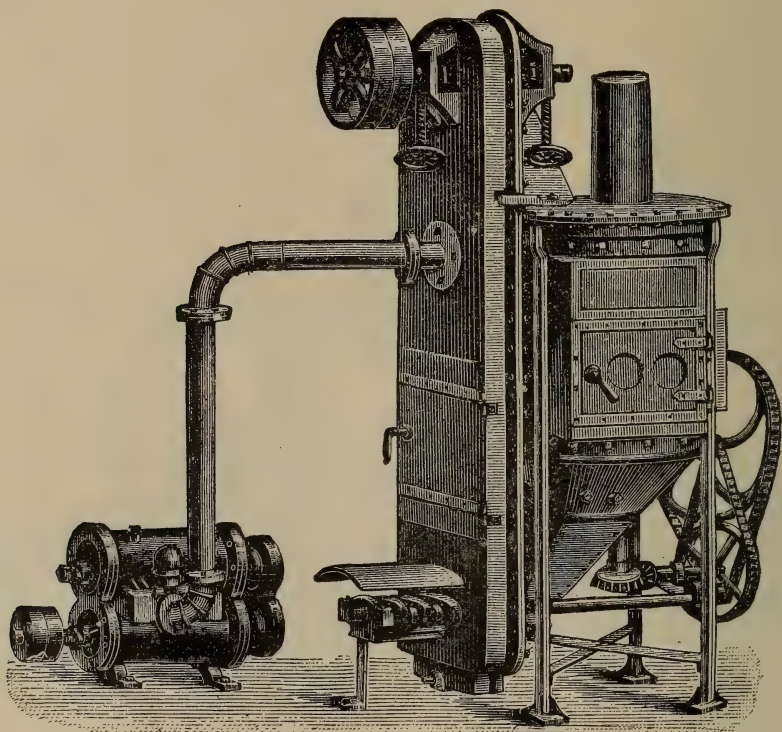


ratus does not use steam, but is simply connected to an air-pressure of from 2 lbs. upward; consequently the work does not become clogged with the damp sand. It does away with the constant handling of the sand or the unsightly endless chain buckets, and requires less room than any apparatus for like purpose.

Other types of sand-blasts are shown in Figs. 85, 86, and 87.

These machines are of great capacity, and all kinds of metals can rapidly and in large quantities be thoroughly freed from adhering impurities. They are arranged as follows: A reservoir on top contains quartz sand or emery powder of a coarser or finer grain according to the harder or softer metal to be treated, or the desired grain of the metallic surface to be

FIG. 85.

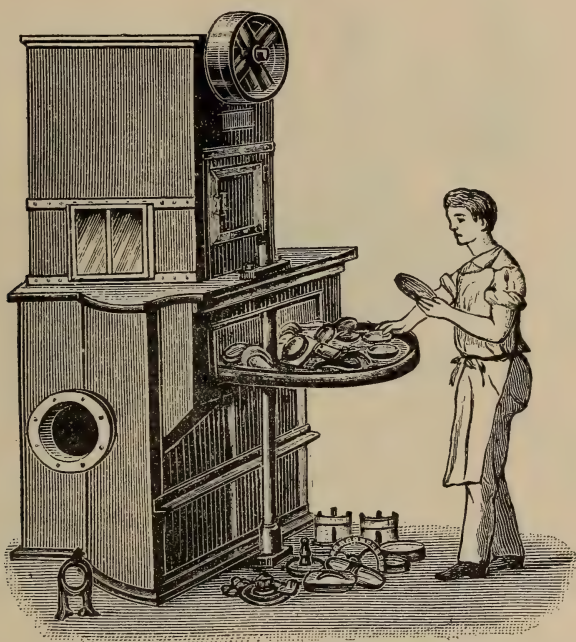


cleansed. The sand runs through a pipe, and on leaving the latter is, by means of a powerful air-current produced by a blower, hurled upon the articles. In place of an air current, a jet of steam may be employed for hurling the sand. For small articles the sand-blasts have been combined with a scouring drum, as shown in Fig. 87.

The uses to which a sand blast can be put are very numerous. The frosting or satin-finishing of silver-ware and other articles, engraving or stenciling of metal or glass, inlaying, removing scale or brazing, the nature of the work being governed by the fineness of the sand used as well as the pressure.

If a clean metallic surface is to be given at one time to a large number of small articles, such as buckles, steel beads, metal

FIG. 26.



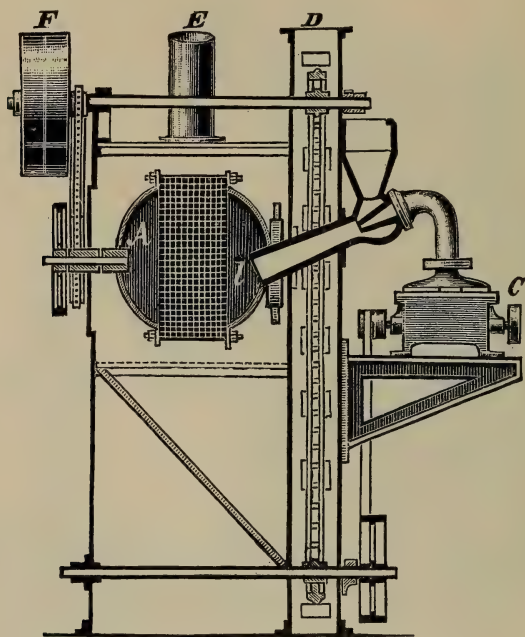
buttons, steel watch chains, ferrules, etc., a *tumbling barrel* or *drum* is frequently used. It generally consists of a cylindrical or polygonal box having a side door for the introduction of the work, together with sharp sand or emery, and is mounted horizontally on an axis furnished with a winch or pulley, so as to be revolved either by hand or power, as may be desired. In order to prevent certain objects, like hooks for ladies' dresses and



the like, from catching each other and accumulating into a mass, a number of nails or wooden pegs are fixed in the interior of the drum.

For ordinary polishing the articles are brought into the tumbling barrels together with small pieces of leather waste (leather shavings) and taken out in one or two days. However, to produce an actually good polish a somewhat more

FIG. 87.



complicated method has to be pursued. The articles are first freed from adhering scale by washing in water containing 5 per cent. of sulphuric acid, rinsed, and dried in a drying chamber or in a pan over a fire. They are next brought into the tumbling barrel together with the sharp sand, such as is used in glass-making, and revolved for about 12 hours, when they are taken from the barrel and freed from the admixed sand by sifting. They are then returned to the barrel, together with soft, fibrous sawdust, to free them from adhering sand, and at the

same time to give them a smoother surface. They are now again taken from the barrel, freed from sawdust and returned to the barrel, together with leather shavings. They now remain in the barrel until they have acquired the desired polish, which, according to the size and shape of the articles and the degree of polish required, may frequently take two weeks or more. Articles of different shapes and sizes are best treated together, time being thereby saved. The process is also accelerated by adding some fat oil to the leather shavings, which, of course, must be omitted when, after long use, the shavings have become quite greasy. The barrel should be filled about half full, otherwise the articles do not roll freely and polishing is retarded. On the other hand, when the barrel is less than half full there is danger of the articles bending, or in case they are hardened, for instance buckles, of breaking.

For many purposes polishing in the tumbling barrel is of great advantage; since, independent of its cheapness, the sharp edges of the articles are at the same time rounded off. However, with articles the edges of which have to remain sharp, the process cannot be employed.

The tumbling barrel in which the articles are treated with sand cannot be used for polishing with leather shavings, it being next to impossible to free it entirely from sand. The barrels should make from 50 to 70 revolutions per minute; if allowed to revolve more rapidly, the articles take part in the revolutions without rolling together, which, of course, would prevent polishing.

The brightening of articles of iron and steel may be simplified by using water to which 1 per cent. of sulphuric acid has been added. The barrel used for the purpose must, of course, be water-tight. By the addition of sand the process is accelerated. Nickel and copper blanks for coins are also cleansed in this manner. They are brought into the tumbling barrel, together with a pickling fluid, and, when sufficiently treated, are taken out, rinsed, dried in sawdust, and finally stamped.

Fig. 88 shows a form of an adjustable oblique tumbling

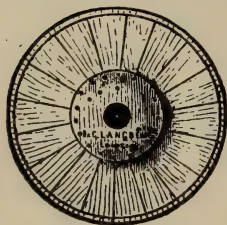
barrel, adapted to clean, smooth, brighten and polish nearly every variety of iron and brass goods. The simplicity and durability of the construction and the rapidity with which the

FIG. 88.



work is done, are distinct advantages. The machine can be used wet or dry. It is adjustable by screw and wheel to any working elevation up to  $50^{\circ}$ . The machine shown in the illustration is designed to carry a barrel 24 inches in diameter, but larger or smaller barrels can be used.

FIG. 89.



*Grinding.*—For grinding the objects for the electro-plating process, wooden wheels covered with leather coated with emery of various degrees of fineness are almost exclusively used. The wooden wheels are made of thoroughly seasoned poplar in the manner shown in

Fig. 89. The separate pieces are radially glued together, and upon each side in the centre a strengthening piece is glued and secured with screws, so that each segment of the wheel is connected with the strengthening piece. The centre of the wheel is then provided with a hole corresponding to the diameter of the spindle of the grinding lathe, to which it is secured by means of wedges. The periphery as well as the sides is then turned smooth. A good quality of leather previously soaked in water and cut into strips corresponding to the width of the wheel is then glued to the periphery, and still further secured by pins of soft wood. When the glue is dry the wheel is again wedged upon the spindle and the leather carefully turned; it is then ready for coating with emery.

With the use of grinding wheels of oak or walnut, covering with leather may be omitted and the emery can be applied directly to the wheels. However, leather-covered wheels are to be preferred since, by reason of their elasticity, better results in grinding are obtained than with uncovered wheels of the above-mentioned varieties of wood.

For grinding soft metals, hard, impregnated felt wheels "set up" with glue and emery are also employed.

For grinding profiled articles preference should be given to wheels without leather covering, and the grinding surface should be fitted to the profile of the article to be ground by cutting with a turning tool.

Grinding wheels of paste-board and of cork waste have recently been introduced. The former are made by coating on both sides thin, round disks of paste-board with glue mixed with emery, and then gluing a sufficient number of such disks one upon the other to form a wheel of the desired width. The wheel is finally subjected to strong pressure under a hydraulic press and dried.

The preparation of cork wheels is a trade secret, and they have been in the market for too short a time to allow of expressing an opinion regarding their durability. They would appear to be very suitable for fine grinding, but are less adapted to preparatory grinding.



For gluing with emery three different kinds of emery are used, a coarse quality (Nos. 60 to 80) for preparatory grinding, a finer quality (No. 00) for fine grinding, and the finest quality (No. 0000) for imparting lustre. The wheels thus coated are termed respectively "roughing wheel," "medium wheel," and "fine wheel." With the first the surface of the objects are freed from the rough crust. The coarse-grained emery used for this purpose, however, leaves scratches, which have to be removed by grinding upon the medium wheel until the surface of the objects shows only the marks due to the finer quality of emery, which are in their turn removed by the fine wheel.

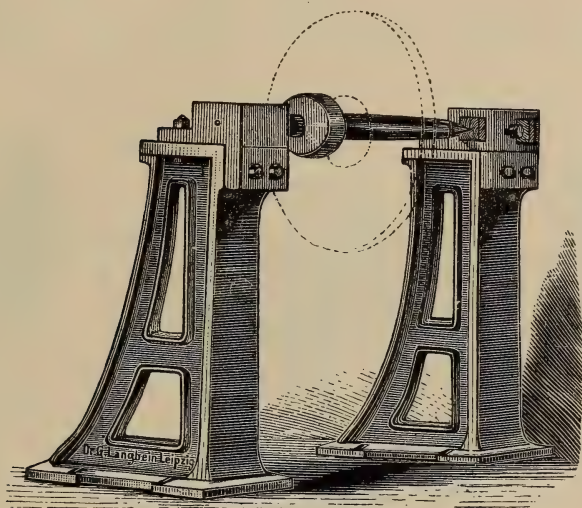
In most cases brushing with a circular bristle brush may be substituted for the last grinding, the articles being moistened with a mixture of oil and emery No. 0000. Care must be had not to execute the brushing, nor the grinding with the finer quality of emery in the same direction as the preceding grinding, but in a right angle to it.

*Treatment of the grinding wheels.*—The coating of the roughing wheels with emery is effected by applying to them a good quality of glue and rolling them in dry, coarse emery powder. For the medium and fine wheels, however, the emery is mixed with the glue and the mixture applied to the leather. When the first coat is dry, a second is applied, and finally a third. The whole is then thoroughly dried in a warm place. Before use, a piece of tallow is held to the revolving disk for the purpose of imparting a certain greasiness to it, and in order to remove any roughness due to an unequal application of the emery it is smoothed by pressing a smooth stone against it. While the preparatory grinding upon the roughing wheel is executed dry, *i. e.*, without the use of oil or fat, in fine grinding the objects are frequently moistened with a mixture of oil and the corresponding No. of emery. When the layer of emery is used up, the remainder is soaked with warm water and scraped off with a dull knife. The leather of the disks on which oil or tallow has been used is then thoroughly rubbed with caustic

lime or Vienna lime \* to remove the greasiness, which would prevent the adherence of the layer of glue and emery to be applied later on. When the leather is thoroughly dry a fresh layer of emery may at once be applied.

To prevent the leather from absorbing an excess of water when moistening the old layer of glue and emery for the purpose of softening it, it is advisable to apply moderately wet

FIG. 90.



clay to the layer and allow it to remain for a few hours when the scraping off of the emery can be readily effected.

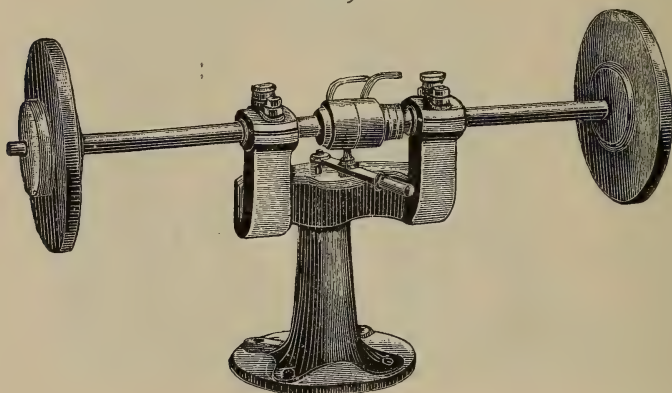
*Grinding lathes.*—For use, the grinding wheels or bobs are wedged upon a conical cast-steel spindle provided with a pulley and working in hard-wood bearings, as plainly shown in Fig. 90. The cast-iron standards are screwed to the floor; the wooden bearings can be shifted forward and backward by wedges and secured in a determined position by a set screw,

\* Vienna lime is prepared from a variety of dolomite which is first burned, then slaked, and finally ignited for a few hours. It consists of lime and magnesia, and should be kept in well closed cans, as otherwise it absorbs carbonic acid and moisture from the air, and becomes useless.

thus facilitating the removal of the spindle after throwing off the belt. The wheels being wedged upon a conical spindle they always run centrically. The changing of the wheels requires but a few seconds, and on account of the slight friction of the points of the spindle in the wooden bearings the consumption of power is very slight.

To avoid the necessity of throwing off the belt while changing the grinding wheels, double machines (Fig. 91) are used, the principle of conical spindles being, however, preserved. The shaft is provided with loose and fast pulley and coupling lever.

FIG. 91.



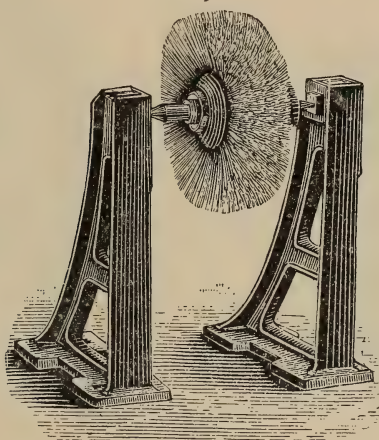
Grinding is executed by pressing the surfaces to be ground against the face of the wheel, moving the objects constantly to and fro. The operation requires a certain manual skill, since, without good reason, no more should be ground away on one place than on another. Special care and skill are required for grinding large round surfaces.

If the objects are not to be treated with the fine wheel, fine grinding is succeeded by brushing with oil and emery by means of circular brushes formed of bristles set in disks of wood (see Fig. 97). Genuine bristles being at present very expensive, vegetable fibre, so-called *fibres*, has been successfully substi-

tuted for them, the wooden wheel being replaced by an iron case, in the bell-shaped cheeks of which the fibre-bundles are secured by means of strong nuts. Before use it is advisable to saturate the fibre-bundles with oil in order to deprive them of their brittleness, and thus improve their lasting quality.

The grinding lathe (Fig. 92) is provided with such a fibre-brush, which can, of course, be just as well placed upon the conical spindles of double machines. The iron case is provided with a conical hole corresponding exactly to the conical spindle, the large frictional surface preventing the turning of the brush upon the spindle or its running off.

FIG. 92.



In regard to grinding the various metals, the procedure, according to the hardness of the metal, is as follows:—

*Iron and steel articles* are first ground upon the roughing wheel, then fine-ground upon the medium wheel, and finally upon the fine wheel, or brushed with emery with the circular brush. Very rough iron surfaces may first be ground upon solid emery wheels before being worked upon the roughing wheel.

For depressed surfaces which cannot be reached with the large emery wheels, small walrus-hide wheels coated with glue



and emery are placed upon the point of the spindle of the polishing lathe (see Fig. 99).

*Brass and copper castings* are first ground upon roughing wheels, which have lost part of their sharpness and will no longer attack iron. They are then ground fine upon the medium wheel, and finally polished upon cloth or felt wheels (bobs). (See below, under *polishing*.)

*Sheets of brass, German silver, and copper*, as furnished by rolling-mills, are only brushed with emery and then polished with Vienna lime or rouge upon bobs.

FIG. 93.

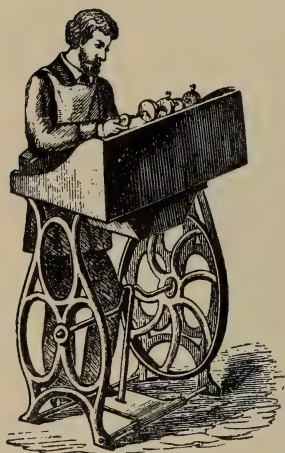
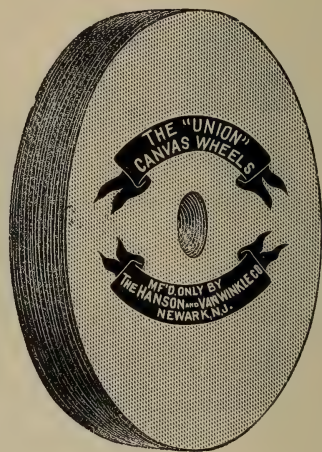


FIG. 94.



*Zinc castings*, as, for instance, those produced in lamp factories, are first thoroughly brushed by means of circular brushes and emery, and then polished upon cloth bobs.

*Sheet zinc* is only polished with Vienna lime and oil upon cloth bobs secured to the spindle shown in Fig. 98.

*Polishing*.—As will be seen from the foregoing, polishing serves for making the articles ready, *i. e.*, the final lustre is imparted to them upon soft polishing wheels with the use of fine polishing powders. The polishing wheels or bobs of fine felt, shirting, or cloth, are secured to the polishing lathe, and,

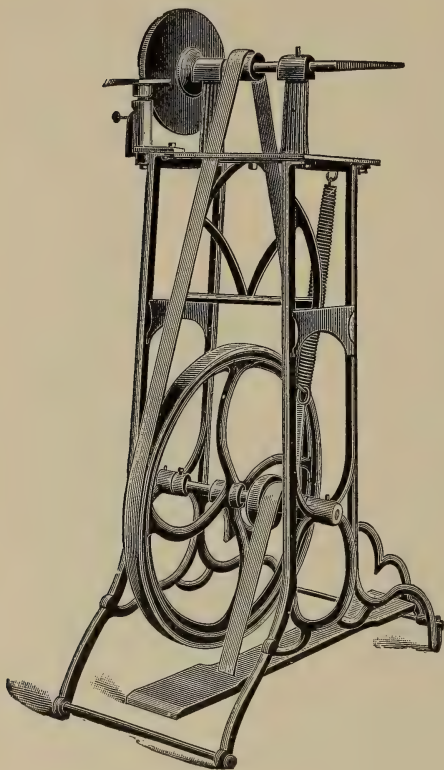
according to the hardness of the metal to be polished, make 2000 to 2500 revolutions per minute. A foot-lathe, such as is shown in Fig. 93, makes generally not over 1800 revolutions per minute. Cloth bobs are made by placing pieces of cloth one upon another in the manner described under "Nickeling of sheet zinc," cutting out the centre corresponding to the diameter of the spindle, and securing the disks of cloth by means of nuts between two wooden cheeks upon the spindle of the polishing lathe. In place of cloth bobs, solid wheels of felt or wooden wheels covered with a layer of felt may be used, especially for polishing smooth objects without depressions, the fineness and softness of the felt depending on the degree of polish to be imparted and the hardness of the metal to be manipulated.

An excellent polishing wheel is the Union canvas wheel, made by the Hanson & Van Winkle Co., of Newark, N. J. It is shown in Fig. 94. It is not glued, but by a special process the weight is reduced, the elasticity and flexibility are increased, and a cloth face is obtained, which combined with the glue, presents a surface that will hold emery better than any other wheel. Being of a flexible nature it easily adjusts itself to the irregularities of the work. No special skill is required to use it, and there is less tendency to "gouge" the work or spoil design. The wheel will do more work with one "setting-up," than any other. It is durable and easily kept in balance.

Another wheel of great flexibility and elasticity is the *walrune wheel* manufactured by the same firm. On account of its flexibility and elasticity, combined with its hardness, it is recommended for hard grinding, and the fact that its face can be turned to any shape—at the same time preserving all the characteristics of hide wheels—will place it before sea-horse or walrus on its merits. One advantage of this wheel is its pliability, which allows it to adjust itself to any inequalities in the coat of emery, and consequently it wears evenly, and being lighter than any other serviceable wheel it is much less liable to injure lathe bearings.

Fig. 95 shows a substantial foot-power grinding and polishing lathe. It is noiseless and with friction-clutch attachment a speed of 2500 to 3000 revolutions per minute can be maintained without effort. There is nothing better for gunsmiths, blacksmiths, skate grinders, locksmiths, bicycle repair shops, jewelers.

FIG. 95.



It is so constructed as to be very rigid and strong to prevent vibration.

Double polishing lathes, according to the American patterns (Figs. 96 and 97), are used for polishing objects of not too large dimensions, while the lathe shown in Fig. 98 serves chiefly for polishing large sheets, the latter being placed upon a smooth wooden support which rests upon the knees of the workman, as will be described later on in speaking of the nickeling of sheet zinc.

Fig. 97 shows a double polishing lathe of larger size. It carries on one side a large felt wheel and a small brush, and upon the other a circular brush and a small walrus-hide buff. The spindle of the small polishing lathe, Fig. 96, carries a cloth bob.

The lathe (Fig. 99) is manufactured by the Hanson & Van Winkle Co., of Newark, N. J. It is shown on a cast-iron pedestal, from which it can be disconnected and placed on a

bench, if required. It is made to run at a speed of 3000 revolutions per minute, at which speed the most satisfactory results are obtained with muslin buffs, etc.

FIG. 96.

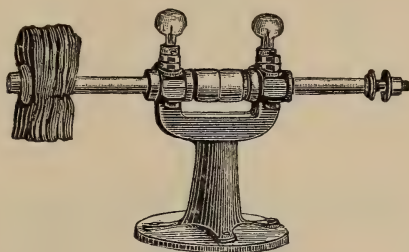


FIG. 97.

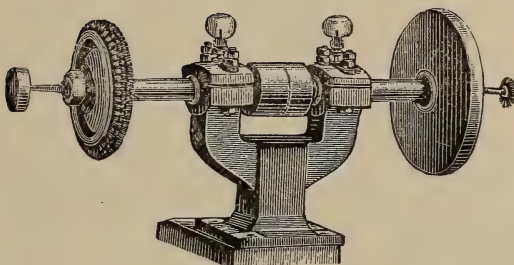
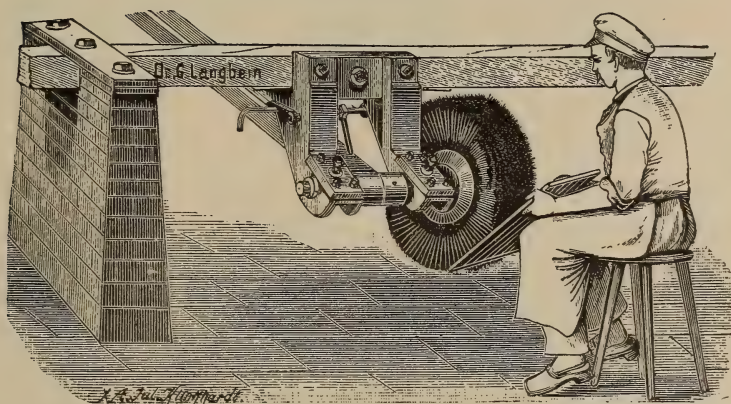


FIG. 98.



The lathe is made with steel spindles, hard-metal bearings,



and is designed for quick speeds. By reason of the distribution of metal it runs without vibration. It stands 10 inches high to centre, has spindle 3 feet long,  $1\frac{1}{4}$  inches diameter, with collars on both ends of spindle. The pulley is 4 inches in diameter,  $3\frac{1}{2}$  inches face. The spindle is 1 inch in diameter between collars. The lathe is furnished with fast and loose pulleys where required. Detachable taper ends are shown, on which the smallest brush can be run.

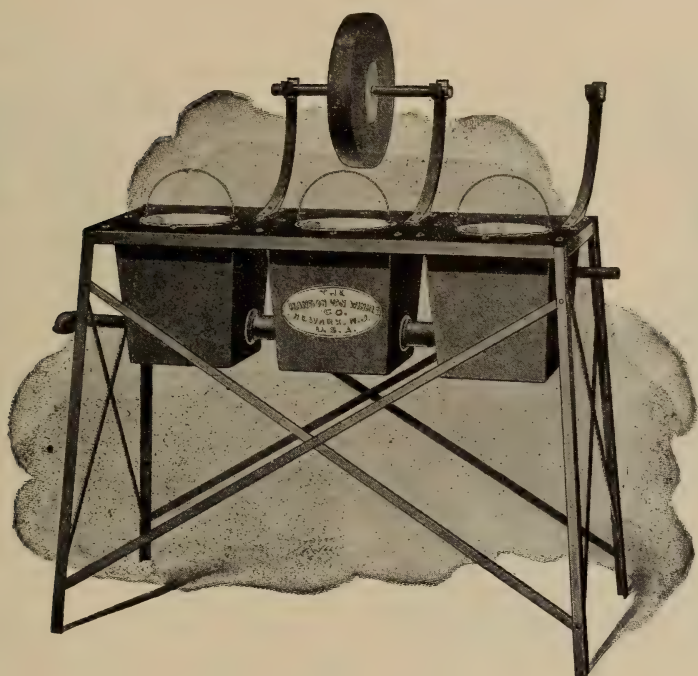
FIG. 99.



Electrically driven grinding and polishing lathes are now furnished by the Hanson & Van Winkle Co., of Newark, N. J. The high speed at which emery and polishing wheels are run necessitate tight belts, heated bearings and the dirt carried by the belt. All this is overcome in these machines. They can be placed so as to secure the best light, the speed is constant, and no power is used in driving countershaft when not in use. The machines are furnished with and without stand.

Polishing rooms are not complete without a good glue pot. The pots used are often home-made affairs, but the steam glue pots shown in Fig. 100 are so superior, and at the same time so low in cost, that it pays every plater to have them. Each pot sits in a separate heater. The heaters are cast-steel chambers through which the steam circulates, keeping the glue at an even heat. These steel chambers also avoid all escaping steam.

FIG. 100.

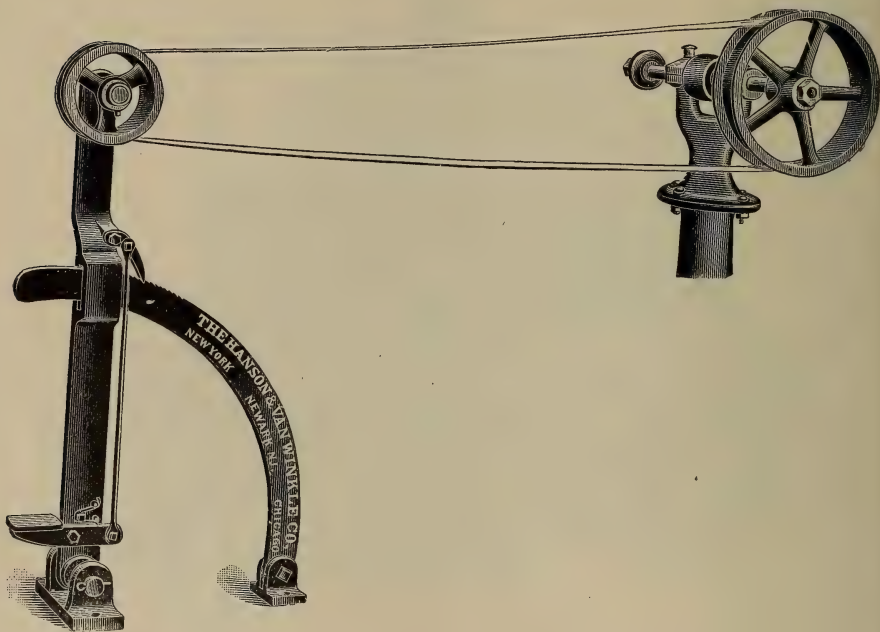


The heaters are fitted with upright arms to support the wheel while "setting up" with glue. This allows the surplus glue to drop back into the glue pot instead of on the floor.

The *belt strapping attachment or endless belt machine* shown in Fig. 101 is manufactured by the Hanson & Van Winkle Co., of Newark, N. J. The demand for machines of this character for polishing bicycle parts has greatly increased, and improve-

ments have from time to time been made, culminating in the present construction, which is much more solid and the adjustment of the tension of the belt can be done without interfering with the operator. There are fewer parts used than in previous machines, and with the flanged wheels that are supplied to go on the pulley lathe, and with the rubber endless belts from 1 to 3 inches and up to 12 feet in length, makes this machine available for all purposes. It is equally available to manufac-

FIG. 101.



turers of saddlery and carriage hardware, and on irregularly shaped articles that cannot be conveniently polished on a circular wheel.

No shop is now complete without one or more flexible shafts for grinding, polishing and buffing. In many ways it will be found a profitable and economical device. For cleaning and grinding heavy castings, for polishing and buffing all metal and

glass, it is a most indispensable tool where power is or can be used to advantage. These shafts, Fig. 102, are made in standard sizes, from  $\frac{1}{4}$ -inch diameter core, suitable for very light work, to  $1\frac{1}{2}$ -inch core, capable of driving a 3-inch drill in iron or steel.

Fig. 103 shows the flexible shaft with part of case and core cut away to show the method of construction. The core is built up by laying up or coiling very small tempered steel wires on a small diameter, each successive layer wound in an opposite direction of large wire, the ends firmly brazed together solid. The fittings are also attached by special brazing. The coil should be well lubricated with animal oil. Never use mineral oil.

Self-acting polishing lathes for sheet-metal will be discussed under "Nickeling of zinc sheet."

According to the hardness of the material to be polished, rouge (ferric oxide, colcothar), tripoli, Vienna lime, etc., in the state of an impalpable powder, and generally mixed with oil, or sometimes with alcohol, are used as polishing agents. For hard metals an impalpable rouge of great hardness (No. F of commerce) is employed, for softer metals a softer rouge (No. F F F), or Vienna lime, tripoli, etc.

It is of advantage to melt the rouge with stearine and a small quantity of tallow, and cast the mixture in moulds with the aid of strong pressure. The sticks thus formed are sufficiently greasy to render the use of oil superfluous. In order to impregnate the surface of the polishing bob with the polishing material, hold one of the sticks for a second against the revolv-

FIG. 102.

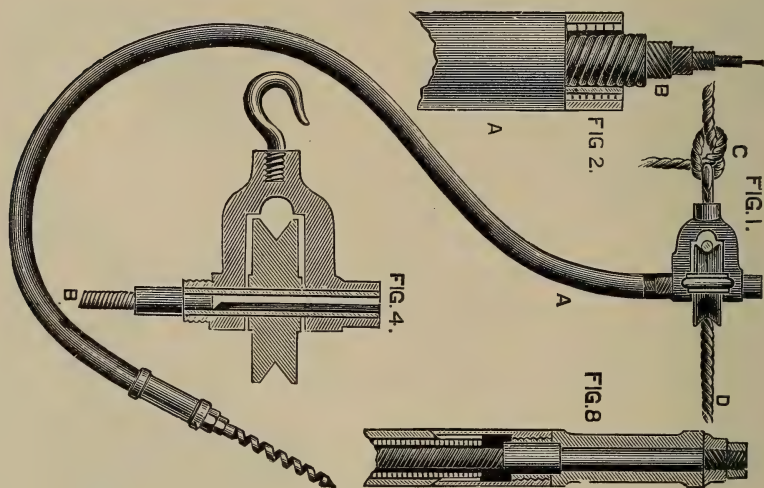




ing wheel, and then polish the objects by pressing them against the wheel, diligently moving them to and fro. The polishing bob must not be too heavily impregnated with rouge, since a surplus of the latter smears instead of cutting well. In polishing with Vienna lime, it is advisable to moisten the objects to be polished with oil, while the polishing bobs are saturated with the lime by holding a piece of it against them.

Another process of polishing, called *burnishing*, is executed by means of tools usually made of steel for the first or *grounding* process, or of a very hard stone, such as agate or blood-

FIG. 103.



stone, for finishing. Burnishing is applied to the final polishing of deposits of the noble metals.

2. *Mechanical treatment during and after the electro-plating process.*—In this connection, *scratch-brushing* the deposits will be first considered, the object of this operation being, on the one hand, to promote the regular formation of certain deposits; and on the other, to affect the physical properties of the deposits; and, finally, to ascertain whether the deposit adheres to the basis-metal.

If it is seen by the irregular formation of the deposit that the basis-metal has not been cleaned with sufficient care by the preparatory scratch-brushing, the object has to be taken from the bath and the defective places again scratch-brushed with the application of water and sand, or pumice-stone, when the object is again pickled and replaced in the bath.

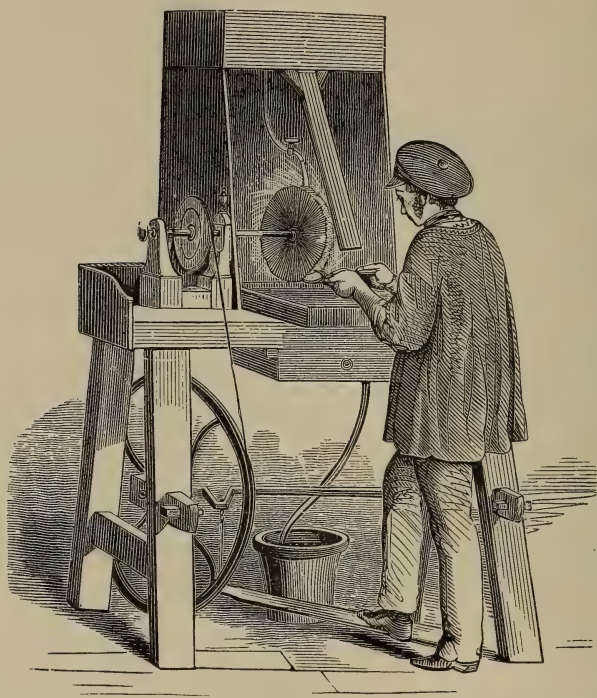
On the other hand, electro-deposited metals are always more or less porous, they having, so to say, a net-like structure, though it may not be visible to the naked eye. By scratch-brushing, the meshes of the net are made closer by particles of metals being forced into them by the brush, and the deposit is thus rendered capable of receiving additional layers of metal. Furthermore, by scratch-brushing the dull deposits acquire a certain lustre which is enhanced by the subsequent polishing process. Finally, by an unsparing application of the scratch-brush, it will be best seen whether the union of the deposit with the basis-metal is sufficiently intimate to stand, without becoming detached, the subsequent mechanical treatment in polishing.

According to the object in view, and the hardness of the deposit to be manipulated, scratch-brushes of steel or brass wire are chosen. For *nickel*, which, as a rule, requires scratch-brushing least, and chiefly only for the production of very thick deposits, steel wire of 0.2 millimetre thickness is taken; for deposits of *copper*, *brass*, and *zinc*, brass wire of 0.2 millimetre; for *silver*, brass wire of 0.15 millimetre; and for *gold*, brass wire of 0.07 to 0.1 millimetre. Scratch-brushing is seldom done dry. The tool as well as the pieces should be constantly kept wet with liquids, especially such as produce a lather in brushing, for instance, water and vinegar, or sour wine, or solutions of cream of tartar or alum, when it is desired to brighten a gold deposit which is too dark. However, the liquid most generally used is a decoction of licorice-root, of horse-chestnut, of marshmallow, of soap-wort, or of the bark of Panama-wood, all of which, being slightly mucilaginous, allow of a gentle scouring with the scratch-brush, with the production of an abundant lather. A good adjunct for scratch-brushing is a

shallow wooden tub containing the liquid employed, with a board laid across it nearly level with the edges, which, however, project a little above. This board serves as a rest for the pieces.

The hand scratch-brush, when operating upon small objects, is held by the workman in the same manner as a paint brush, and is moved over the object with a back and forward motion

FIG. 104.



imparted by the wrist only, the forearm resting on the edge of the tub. For larger objects, the workman holds his extended fingers close to the lower part of the scratch brush, so as to give the wires a certain support, and, with raised elbow, strikes the pieces repeatedly, at the same time giving the tool a sliding motion. When a hollow is met with, which cannot be scoured longitudinally, a twisting motion is imparted to the tool.

The lathe brush (Fig. 104) is mounted upon a spindle, and is provided above with a small reservoir to contain the lubricating fluid, a small pipe with a tap serving to conduct the solution from this to a point immediately above the revolving brush. The top of the brush revolves towards the operator, who presents the object to be scratch-brushed to the bottom. The brush is surrounded by a wooden cage or screen to prevent splashing. To protect the operator against the water projected by the rapid motion, there is fixed to the top of the frame a small inclined board, which reaches a little lower than the axis of the brush without touching it. This board receives the projected liquid, and lets it fall into a zinc trough, which forms the bottom of the box. Through an outlet provided in one of the angles of the trough, a rubber tube conveys the waste liquid to a reservoir below. After scratch-brushing every trace of the lubricating liquid must be washed away before placing or replacing the objects in the bath.

The finished electro-plated objects are first rinsed in clean water to remove the solution constituting the bath adhering to them. They are next immersed in hot water, where they remain until they have acquired the temperature of the water, and are then quickly rubbed with dry, hot sawdust. It is best to use sawdust of soft wood, free from tannin, such as maple, poplar, or pine. Oak sawdust is not suitable for the purpose on account of its content of tannin, which imparts a dirty coloration to the electro-deposits. Boxwood sawdust, though much used, is not sufficiently absorbent, and sticks to the moist objects. The sawdust used must be freed from coarser particles of wood by sifting. For holding the sawdust a zinc box with double bottom is frequently used, which is heated by waste steam or some other process. In order to remove all moisture from the pores it is advisable to place plated objects of iron and steel for a few hours in an oven heated to between  $140^{\circ}$  and  $175^{\circ}$  F. A very good method of freeing nickeled objects from all moisture which may have collected in the pores is to immerse them for about ten minutes in *boiling* linseed oil, and, after allowing



them to drain off, to remove the adhering oil by rubbing with sawdust. According to some electro-platers, the deposit of nickel thus treated loses its brittleness and will stand bending several times, for instance, wire, sheets, etc., without breaking. Experiments made by Dr. George Langbein did not confirm these statements, but the security against rust of the nickeled iron objects is found to be considerably enhanced by boiling in linseed oil.

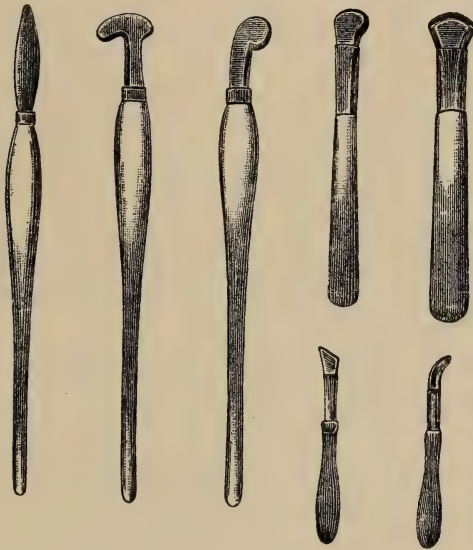
The electro-plated objects, when dry, are finely polished, which is effected upon polishing bobs of fine felt, cloth, or flannel, with the use of fine rouge, Vienna lime, tripoli, etc., or by burnishing.

*Nickel deposits* are almost without exception polished upon cloth or felt bobs with rouge or Vienna lime and oil. *Copper and brass deposits* are polished with fine flannel bobs, the polishing powder being applied very sparingly. *Deposits of tin* are generally only scratch-brushed, it being impossible to impart great lustre to this metal by polishing with bobs. After drying, the deposit is polished with whiting. *Deposits of gold and silver* as well as of *platinum* are polished by burnishing, the steel burnisher being used for the *grounding* process, and an agate or bloodstone burnisher for finishing. The operation of burnishing is carried on as follows: Keep the tool continually moistened with soap-suds. Take hold of the tool very near to the end, and lean very hard with it on those parts which are to be burnished, causing it to glide by a backward and forward motion without taking it off the piece. When it is requisite that the hand should pass over a large surface at once without losing its point of support on the work bench, be careful in taking hold of the burnisher to place it just underneath the little finger. By these means the work is done more quickly, and the tool is more solidly fixed in the hand. The burnishers are of various shapes to suit the requirements of different kinds of work, the first rough burnishing being often done by instruments with comparatively sharp edges, while the finishing operations are accomplished with rounded ones. Fig. 105

illustrates the most common forms of burnishers of steel and agate. Both must be free from cracks and highly polished. To keep them free from blemishes they are from time to time polished by vigorously rubbing them with fine tin putty, rouge or calcined alum upon a strip of leather fastened upon a piece of wood which is placed in a convenient position upon the work bench.

The objects polished with Vienna lime and oil, or with rouge, have to be freed from adhering polishing dirt, which, with flat

FIG. 105.



smooth objects, is effected by wiping with a flannel rag and Vienna lime, and in those with depressions or matted surfaces by brushing with a soft brush and soap-water, and then drying in sawdust.

#### *B. Chemical Treatment.*

While it is the aim of the mechanical treatment to prepare a pure metallic, and at the same time a smoother, surface, the

chemical preparation of the objects serves, on the one hand the purpose of facilitating the mechanical treatment by softening and dissolving the impurities of the surface and, on the other, of freeing the mechanically treated objects from adhering oil, grease, dirt, etc., so as to bring them into the state of *absolute purity* required for the electro-plating process.

*Pickling and dipping.* The composition of the pickling liquor varies according to the nature of the metal to be treated.

*Cast-iron and wrought-iron articles* are pickled in a mixture of 1 part by weight of sulphuric acid of 66° Bé. and 15 parts by weight of water.\*

To cleanse badly rusted iron articles without attacking the iron itself, it is recommended to pickle them in a concentrated solution of chloride of tin, which, however, should not contain too much free acid, as otherwise the iron is attacked. Bucher recommends a pickle composed as follows: Dissolve 3 ½ ozs. of chloride of tin in 1 quart of water, and 1 ½ drachms of tartaric acid in 1 quart of water. Pour the former solution into the latter, and add 20 cubic centimeters of indigo solution diluted with 2 quarts of water. The object of the addition of indigo is not plain.

An excellent pickle for iron is also obtained by mixing 10 quarts of water with 28 ozs. of concentrated sulphuric acid, dissolving 2 ozs. of zinc in the mixture, and adding 12 ozs. of nitric acid. This mixture makes the iron objects bright, while in dilute sulphuric or hydrochloric acid they become black.

For many cases pickling may advantageously be effected in the electrolytic way. Suspend the articles in a weak acid bath (hydrochloric or sulphuric acid), connect them with the positive pole of a source of current, and suspend opposite to them a sheet of metal (copper or brass), which is connected with the negative pole.

The duration of pickling depends on the more or less thick layer of scale, etc., which is to be removed or softened. The

\* The acid should be poured into the water; not the water into the acid.

process may be considerably assisted and the time shortened by frequent scouring with sand or pumice. The pickled articles are rinsed in cold water, then immersed in hot water, and dried in sawdust. In order to neutralize the acid remaining in the pores, it is advisable to make the rinsing water alkaline by the addition of caustic potash or soda, etc.

*Zinc* objects are only pickled when they show a thick layer of oxide, in which case pickling is also effected in dilute sulphuric or hydrochloric acid, and brushing with fine pumice. A very useful pickle for zinc consists of sulphuric acid 100 parts by weight, nitric acid 100, and common salt 1. The zinc objects are immersed in the mixture for one second, and then quickly rinsed off in water which, should be frequently changed.

*Copper*, and its alloys *brass*, *bronze*, *tombac*, and *German silver*, are cleansed and brightened by dipping in a mixture of nitric acid, sulphuric acid, and lampblack, a suitable pickle consisting of sulphuric acid, of 66° Bé., 50 parts by weight, nitric acid, of 36° Bé., 100, common salt 1, and lampblack 1. In order to remove the *brown* coating, due to cuprous oxide, the objects are first pickled in dilute sulphuric acid, and then dipped for a few seconds, with constant agitation, in the above-mentioned pickle until they show a bright appearance. They are then immediately rinsed in water to check any further action of the pickle.

If objects of copper or its alloys are not to be subjected, after pickling, to further mechanical treatment, or are to be at once placed in the electro-plating bath, it is best to execute the pickling process in two operations by treating them in a *preliminary pickle* and brightening them in the *bright-dipping bath*. The *preliminary pickle* consists of nitric acid, of 36° Bé., 200 parts by weight, common salt 1, lampblack 2. In this preliminary pickle the articles are allowed to remain until all impurities are removed, when they are rinsed in a large volume of water, dipped in boiling water, so that they quickly dry, and plunged into the *bright-dipping bath*, which consists of nitric acid, of 40° Bé., 75 parts by weight, sulphuric acid, of 66° Bé., 100, and



common salt 1. It is not advisable to bring the objects which have passed through the preliminary pickle and rinsing water directly, while still moist, into the bright-dipping bath, since for the production of a beautiful pure lustre the introduction of water into the bright-dipping bath must be absolutely avoided.

Hence the objects treated in the preliminary pickle should first be dried by heating in hot water, shaking the latter off.

Potassium cyanide, dissolved in ten times its weight of water, is often used instead of the acid pickle for brass, especially when it is essential that the original polish upon the objects should not be destroyed, as in the preparation of articles for nickel-plating. The objects should remain in this liquid longer than in the acid pickle, because the metallic oxides are far less soluble in this than in the latter. In all cases the final cleaning in water must be observed.

All acid pickles used for different kinds of work should be kept distinct from each other, so that one metal may not be dipped into a solution containing a more electro-negative metal, which would deposit upon it by chemical exchange.

The pickled objects must not be unnecessarily exposed to the air, and should be transferred as quickly as possible from the pickle to the wash-waters, and then to the electro-plating bath, or, if this is not feasible, kept under pure water. Pickled objects which are not to be plated are carefully washed in water, which should be frequently changed, rinsed, drawn through a solution of tartar, and dried by dipping in hot water and rubbing with saw-dust.

Places soldered with soft solder, as well as parts of iron, become black by pickling, and have to be brightened by scouring with pumice, or by scratch-brushing.

*Matting.* It is frequently required that objects of brass or other alloys of copper should be given a dead surface so that after plating they show a beautiful matt lustre. Beautiful effects may by this means be obtained, especially in the bronze ware industry. Matting may be effected in various ways, either chemically, mechanically, or by galvanoplasty.

*Matting by chemical means* is available only for brass, copper and its alloys, and is effected by means of the so-called matt-pickle. The objects are first treated in the preliminary pickle mentioned above, and are then dipped in a mixture of nitric acid of  $36^{\circ}$  Bé.  $6\frac{1}{2}$  lbs., sulphuric acid of  $66^{\circ}$  Bé. 4.4 lbs., common salt  $\frac{1}{2}$  oz., zinc sulphate  $\frac{1}{3}$  to  $\frac{1}{2}$  oz. Dissolve the zinc sulphate in  $3\frac{1}{2}$  ozs. of water and add the solution to the cold mixture of the acids and the salt. The greater the quantity of zinc sulphate used, the more matt the articles treated with this matt-dipping bath will be.

According to the degree of matt desired the articles are for a shorter or longer time allowed to remain in the cold matt-dipping bath. By heating the bath the matting action is accelerated. When taken from the bath, the articles are several times thoroughly washed in water. As the articles come from the matt-dipping bath with a faded, earthy appearance, they are plunged momentarily into a bright dipping-bath and then quickly rinsed in a large volume of water. The articles must not be allowed to remain too long in the bright-dipping bath, otherwise the matt disappears entirely.

Lead vessels are frequently used for matt-dipping. To heat them they are placed in hot water.

For the production of a matt-grained surface by pickling, the following mixture may be recommended: Saturated solution of potassium dichromate 1 part by volume, and concentrated hydrochloric acid 2 parts by volume. In this mixture the brass articles are allowed to remain several hours. They are then rapidly drawn through the bright-dipping bath and rinsed in a large volume of water frequently renewed.

A delicate matted surface may be produced by electrolytic pickling or etching. The process is the same as described above under iron.

*Matting by mechanical means.* The most simple method of matting is by means of brass or steel wire brushes. The wires of the brushes must, of course, be harder than the metal to be matted, and hence, for brass, copper, tombac, German silver,

silver, etc., steel wire brushes will have to be employed, and for Britannia, gold and zinc, brass wire brushes. A swing brush for matting, with four knots of medium brass or steel wire, is shown in Fig. 78, p. 134.

The character of the matt produced depends on the thickness of the wire of the brushes. Thicker wire gives a matt of a coarser grain, and thinner wire one of a finer grain.

In larger establishments matting is frequently effected by the sand blast. Machines for this purpose will be described later on. The coarser the sand the coarser the grain of the matt will be.

*Matting by galvanoplasty.* This is effected by providing the articles, previously thoroughly cleansed, with a galvanoplastic deposit, employing a weak current for the purpose.

The solution used consists of water 1 quart, blue vitriol  $5\frac{1}{2}$  ozs., sulphuric acid 1 oz. The electro-motive force required for this bath is 0.75 to 1 volt.

If articles of zinc, Britannia, etc., are to be matted in this manner, they must previously be coppered in a bath containing potassium cyanide (see under Coppering), and the soft matt which is only obtained in the acid copper bath, is then produced by suspending the articles in the above-mentioned solution.

The matt produced by galvanoplasty is very effective, and this method is largely employed for matt gilding uniform buttons, handles of walking sticks and umbrellas, etc.

Very beautiful effects are produced by covering with lacquer the portions of a lustrous surface which are to retain their lustre and matting the other portions in the manner above described. The covering layer is then removed and the entire article nicked, silvered or gilded.

Generally speaking, it may be said that less depends on the composition of the pickle than on quick and skillful manipulation; and as good results have always been obtained with the above-mentioned mixture, there is no reason for repeating the innumerable receipts given for pickles. The main points are to

have the acid mixture as free from water as possible, further to develop hyponitric acid, which is effected by the reduction of nitric acid in consequence of the addition of organic substances (lampblack, sawdust, etc.), and of chlorine, which is formed by the action of the sulphuric acid upon the common salt. The volume of the dipping bath should not be *too small*, since in pickling the acid mixture becomes heated and the increased temperature shows a very rapid, frequently not controllable, action, so that a corrosion of small articles may readily take place. It is therefore necessary to allow the acid mixture, after its preparation, to thoroughly cool off. Pour the sulphuric acid into the nitric acid (*never the reverse!*), and allow the mixture, which thereby becomes strongly heated, to cool off to at least the ordinary temperature.

In order to be sure of the uniform action of the pickle upon all parts, it is, in all cases, advisable previous to pickling to free the articles from grease by one of the methods given later on.

In pickling abundant vapors are evolved which have an injurious effect upon the health of the workmen, and corrode metallic articles exposed to them. The operation should, therefore, be conducted in the open air, or under a well-drawing vapor flue.

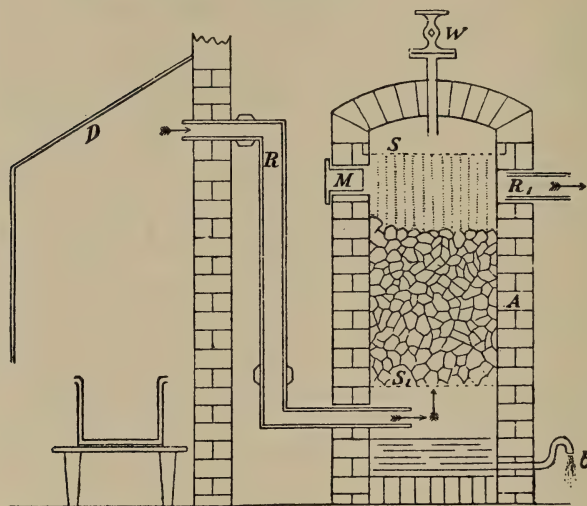
In large establishments it may happen that the quantity of escaping acid vapors is so large as to become a nuisance to the neighborhood, which the proprietors may be ordered by the authorities to abate. The evil is best remedied by a small absorbing plant, as follows:—

Connect the highest point of the vapor-flue *D* (Fig. 106) by a wide clay pipe *R* with a brick reservoir, *A*, laid in cement, so that *R* enters *A* a few centimeters above the level of the fluid, kept constantly at the same height by the discharge pipe *b*. Above, the reservoir is closed by a vault through which the water conduit *W* is introduced. Below the sieve *S*, which is made of wood and coated with lacquer, a wide clay pipe *R*<sub>1</sub> leads to the chimney of the steam boiler; or the suction pipe of an injector is introduced in this place, into which the air from



the vapor-flue is sucked through the reservoir and allowed to escape into the open air or into a chimney. Through the man-hole *M*, the sieve-bottom *S* of the reservoir is filled with large pieces of chalk or limestone. The manner of operating is now as follows: A thin jet of water falls upon *S*, where it is distributed and runs over the layer of chalk. The air of the pickling room saturated with acid vapor moves upward in consequence of the draught of the chimney of the steam boiler, the injector or the ventilator, and yields its content of acid to the layer of chalk, while the neutral solution of calcium nitrate and calcium chloride, which is thus formed, runs off through *b*.

FIG. 106.



The absorption of the acid vapors may, of course, be effected by apparatus of different construction, but the one above described may be recommended as being simple, cheap, and effective.

The considerable consumption of acid for pickling purposes in large establishments makes it desirable to regain the acid and metal contained in the exhausted dipping baths. The following process has proved very successful for this purpose:

Mix the old dipping baths with  $\frac{1}{4}$  their volume of concentrated sulphuric acid, and bring the mixture into a nitric acid distilling apparatus. Distil the nitric acid off at a moderate temperature, condense it in cooled clay-coils, and collect it in glass balloons. To the residue in the still add water, precipitate from the blue solution, which contains sulphate of copper and zinc, the copper with zinc waste, and add zinc until evolution of hydrogen no longer takes place. Filter off the precipitated copper through a linen bag, wash, and dry. The fluid running off, which contains zinc sulphate, is evaporated to crystallization and yields quite pure zinc sulphate, which may be sold to dye-works, or for the manufacture of zinc-white.

According to local conditions, for instance, if the zinc sulphate cannot be profitably sold in the neighborhood, or zinc waste cannot be obtained, it may be more advantageous to omit the regaining of zinc from the dipping baths. In this case, the fluid which is obtained by mixing the contents of the still with water is compounded with milk of lime until it shows a slightly acid reaction. The gypsum formed is allowed to settle, and after bringing the supernatant clear fluid into another reservoir, the copper is precipitated by the introduction of old iron. The first rinsing waters in which the pickled objects are washed are treated in the same manner. The precipitated copper is washed and dried.

*Removal of grease and cleansing.* These two operations must be executed with most painstaking exactness because on them chiefly depends the success of the electro-plating process. Their object is to remove every trace of impurity, be it due to the touching with the hands, or to the manipulations in grinding and polishing, and to get rid of the layer of oxide which is formed in removing the grease with lyes and other agents.

According to the preparatory treatment of the articles the removal of grease is a more or less complicated operation. Large quantities of oily or greasy matter should be removed by washing with benzine or petroleum, it being advisable to execute this operation immediately after grinding and polish

ing, so that the oil used in these operations has no chance of hardening, as is frequently the case with articles preparatively polished with Vienna lime and stearine oil. Instead of cleaning with benzine or petroleum, the articles, as far as their nature allows, may be boiled in a hot lye consisting of 1 part of caustic potash or soda in 10 of water, until all the grease is saponified, when the dirt consisting of grinding powder, can be readily removed by brushing. In place of solution of caustic alkalies, hot solution of soda or potash may be used, but its action is much slower and offers no advantages. Objects of tin, lead and Britannia must be left in contact with the lye for a short time only, as otherwise they are attacked by it.

The articles thus freed from the larger portion of grease are first rinsed in water, and then, for the removal of the last traces of grease, are brushed with a bristle brush and a mixture of water, quick-lime and whiting until, when rinsed in water, all portions appear equally moistened and no dry spots are visible.

The lime mixture or paste is prepared by slaking freshly-burnt lime, free from sand, with water to an impalpable powder, mixing 1 part of this with 1 part of fine whiting, and adding water, stirring constantly, until a paste of the consistency of syrup is formed.

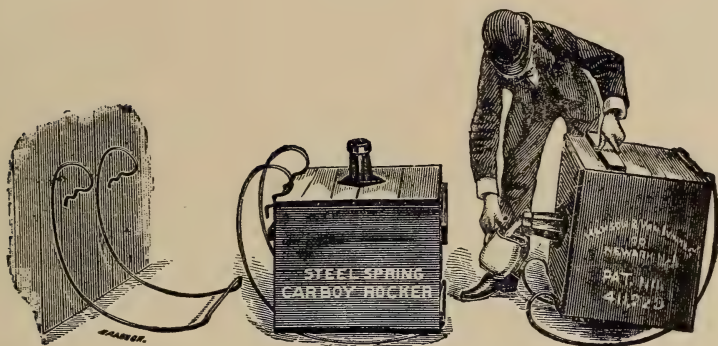
The shape of many objects presents certain difficulties in the removal of grease, as the deeper portions cannot be reached with the brush, as, for instance, in skates, which often are to be nicked in a finished state. In this case the objects are drawn in succession through three different benzine vessels. In the first benzine most of the grease is dissolved, the rest in the second, while the third serves for rinsing off. When the benzine in the first vessel contains too much grease, it is emptied and filled with fresh benzine, and then serves as the third vessel, while that which was formerly the second becomes the first, and the third the second. After rinsing in the third benzine vessel, the objects are plunged in hot water, then for a few seconds dipped in thin milk of lime, and finally thoroughly

rinsed in water. It is recommended not to omit the treatment with milk of lime of objects freed from grease with benzine.

To avoid subsequent touching with the hands the objects, before freeing them from grease, must of course be tied to the metallic wires (of soft copper) by which they are suspended in the electro-plating bath. In removing the grease by the wet method a layer of oxide scarcely perceptible to the eye is frequently formed upon the metals. This layer of oxide has to be removed, the liquid used for the purpose varying, of course, with the nature of the layer.

Objects of *iron* and *steel* as well as of *zinc* are momentarily plunged in a mixture of sulphuric acid 1 part by weight and

FIG. 107.



water 20 parts, and quickly rinsed off in clean water. Highly polished objects of iron and steel, after being treated with this mixture, are best again rapidly brushed with lime paste, and, after rinsing off quickly, immediately brought into the electro-plating bath.

*Copper, brass, bronze, German silver, and tombac* are best cleaned with a dilute solution of potassium cyanide, 1 part of 60 per cent. potassium cyanide in 15 to 20 of water. The objects are then quickly rinsed off and placed in the electro-plating bath.

*Lead* and *Britannia* may be treated with water slightly acidulated with nitric acid.



The *steel spring carboy rocker* shown in Fig. 107 overcomes the difficult and dangerous operation of tilting heavy carboys containing acids. It is the acme of convenience and simplicity. It empties the carboy with ease, saves waste of contents and time in handling, and prevents danger to the person and clothing of the operator. It is very strong, and can be hung up out of the way when not in use.

## CHAPTER VI.

### PROCESSES OF ELECTRO-DEPOSITION.

NEXT to the proper mechanical and chemical preparations of the objects, the success of the process of electro-deposition depends on the suitable composition of the baths, and the current-strength which is conducted into the baths for the precipitation of the metals. In regard to the latter the most essential conditions have already been discussed in Chap. IV., "Electro-plating Plants in General," and will be further referred to in speaking of the several electro-plating processes. Hence, the general rules which have to be observed in the preparation of the baths will first be considered.

Water being the solvent used in the preparation of all baths, its constitution is by no means of such slight importance as is frequently supposed.

Spring and well water often contain considerable quantities of lime, magnesia, common salt, iron, etc., the presence of which may cause various kinds of separations in the baths. On the other hand, river water is frequently impregnated to such an extent with organic substances that its employment without previous purification cannot be recommended. No doubt, distilled water, or in want of that rain water, is the most suitable for the preparation of baths. However, rain water collected from metal roofs should not be used, nor that running off from other roofs, it being contaminated with dust. When used, it should be caught in vessels of glass, earthenware, or wood, free from tannin, and filtered. Where river or well water has to be employed, thorough boiling and filtering before use are absolutely necessary in order to separate the carbonates of the alkaline earths held in solution. By boiling, a possible content of sulphuretted hydrogen is also driven off.

Another important factor is the purity of the chemicals used for the baths, the premature failure of the latter being in most cases caused by the unsuitable nature of the chemicals, which also frequently gives rise to abnormal phenomena inexplicable to the operator. Chloride of zinc, for instance, may serve as an example. It is found in commerce in very varying qualities, it being prepared for dyeing purposes with about 70 per cent. actual content of chloride of zinc, for pharmaceutical purposes with about 90 per cent., and for electro-plating purposes with 98 or 99 per cent. Now it will readily be seen that if an operator who is preparing a brass bath according to a formula which calls for pure chloride of zinc uses a preparation intended for dyeing purposes, there will be a deficiency of metallic zinc in the bath, and the content of copper in the bath being too large in proportion to the zinc present, will cause reddish shades in the deposits.

Likewise, in case the operator uses potassium cyanide of low content, when the formula calls for a pure article with 98 per cent., he will not be able to effect the solution of copper or zinc salts with the quantity prescribed. Furthermore, potassium cyanide, in the preparation of which prussiate of potash containing potassium sulphate is used, will cause, by reason of the formation of potassium sulpho-cyanide, various disturbing influences (formation of bubbles in the deposit), the explanation of which is difficult to the operator, who, trusting to the purity of the chemicals, seeks elsewhere for the causes of the abnormal phenomena.

Sodium sulphate may in a similar manner cause great annoyance if the suitable preparation is not used. There is a crystallized neutral salt which is employed for many gold-baths, and also the sodium bisulphite in the form of powder which serves for the preparation of copper and brass baths. If the latter should be used in the preparation of gold baths, the gold would be reduced from the solution of its salts and precipitated as a brown powder.

Or, if in preparing nickel baths a salt containing copper is

used, the nickeling will never be of a pure white color, but show shades having not even a distant resemblance to the color of nickel.

The above mentioned examples will suffice to show how careful the operator must be in the selection of the sources from which he obtains his supplies. It may here be mentioned that all the directions given in the following pages refer to chemically pure products; where products of a lower standard may be used their strength is especially given.

For the *concentration* of the various baths, no general rules can be laid down; neither can the determination of the density of the baths by the hydrometer be relied on. If electro-plating solutions consisted of nothing but the pure metallic salts, the specific gravity, which is indicated by the hydrometer-degrees, might serve for an estimation of their value. But such an estimation is often apt to prove deceptive, since, to decrease the resistance, the baths also require conducting salts, and by the addition of a larger quantity of them the specific gravity of a bath may be increased to any extent without the content of the more valuable metal being greater than in a bath showing fewer hydrometer-degrees.

When the operator is acquainted with the composition of the baths, and knows how many degrees Bé. a fresh bath should show when correctly prepared, he can draw a conclusion as to the condition of the bath by changes in the specific gravity. If, for instance, a nickel bath when freshly prepared shows the standard specific gravity—70° Bé.—for nickel baths, and it shows later on 90° Bé., the greater specific gravity is due either to evaporation of water or to excessive refreshing or strengthening of the bath. Such a bath generally yields dark or spotted nickeling, the deposit is formed in a sluggish manner, and readily scales off with a stronger current. The operator in this case may recognize from the hydrometer, that the cause of these phenomena is not due to a contamination of the bath, but to its over-concentration. Baths, when too concentrated, readily deposit salts in crystals on the anodes and the sides of



the vats, which should by no means take place, and there is even danger of microscopic crystals depositing upon the articles and causing holes in the deposit.

A plating bath should never be poor in metal, as otherwise it soon becomes exhausted, and besides the deposits form more slowly and with less density than in baths with a correct content of metal.

Hence in summer when the temperature of the baths is naturally higher, they can be made more concentrated than in winter. If crystals are separated, even when a bath shows a temperature of  $58^{\circ}$  F., they should be removed and dissolved in hot water. The solution is returned to the bath and water is added to the latter until the formation of crystals ceases.

In order that all strata of the bath may show an equal content of metal, it is advisable in the evening, after the day's work is done, to thoroughly stir up the solution with a wooden crutch. For practical reasons the baths are generally made one-quarter to one-third deeper than corresponds to the lengths of the objects to be plated. In consequence of this, the strata of fluid between the anodes and the objects become poorer in metal than those on the bottom, and the object of stirring up is to restore the same concentration to all portions of the bath.

While stirring up the bath, it is also advisable to see whether any metallic articles have become detached from the slings and dropped to the bottom of the vat. Such articles must be taken out, since they are dissolved by some baths, the latter being thereby spoiled. This examination must be especially thorough with nickel baths.

The strata of fluid which come in contact with the anodes become, by the absorption of metal, specifically heavier than the other strata and sink to the bottom of the vat, while, on the other hand, the strata of fluid which yield metal to the articles become specifically lighter and rise to the top. A partial compensation, of course, takes place by diffusion, but not a complete one, and from this cause arise several annoyances. The heavier and more saturated fluid offering greater

resistance to the current, the anodes are attacked chiefly on the upper portions where the specifically lighter layer of fluid is; practically this is proved by the appearance of the anodes, which, at first square, after being for some time used assume the shape shown in Fig. 108.

FIG. 108.



On the other hand, the portions of the cathodes (objects) which come in contact, near the surface, with strata of fluid poorer in metal, acquire a deposit of less thickness than the lower portions which dip into the bath where it is richer in metal. Now, if the bath also contains free acid, and if there is a considerable difference in the specific gravity of the lower and upper strata of fluid, the electrode, which touches both strata, produces a current, the effect of which is that metal dissolves from the upper portions and deposits upon the lower. This explains the phenomenon that a deposit on the upper portions of the objects may be redissolved, even when a current, which, however, must be very weak, is conducted into the bath from an external source.

Many authors, therefore, go so far as to demand that during the electro-plating process the baths should be kept in constant agitation by mechanical means. This, however, is scarcely necessary, because a homogeneity of the solution is to a certain extent effected by the agitation of the fluid in suspending and taking out the objects. Hence as long as objects are put in and taken out an agitation naturally takes place in which all the strata of fluid between the objects and anodes take part, while only the deepest strata, which do not come into contact with the objects and the anodes, remain in a state of stagnation.

Constant agitation of the plating solution is of advantage in silvering and in galvano-plastic reproduction in the acid copper bath, in which the articles have to remain four to five and eight to ten hours. With constant agitation of the bath it is possible to work with a greater current-tension, whereby the deposits

are finished in a shorter time; and in silvering, the formation of current-streaks is, to a certain extent, avoided; and in galvanoplastic reproduction, the formation of so-called blooms. In nickeling, with constant agitation of the bath, heavier deposits can, without doubt, be obtained in a shorter time and without premature deadening of the deposit.

Constant agitation effects also the more rapid removal of the hydrogen-bubbles which form on the articles, but the same end is attained without complicated contrivances by the operator accustoming himself to strike the object-rod a slight blow with the finger each time he suspends an object.

The plating apparatus described below may here be referred to.

*Bossard mechano-electroplating tanks.* These tanks are patented devices in which the work to be plated is automatically drawn through the bath at a controllable rate of speed. There are two styles of these devices, namely, the "*long tank*" and the "*circular tank*."

The advantages claimed by the inventor from the shape and general construction of these devices are as follows:

1. The work to be plated, as it is drawn through the bath, continuously stirs the latter, thereby keeping it in active chemical condition. The hydrogen bubbles formed on the work are constantly dislodged, the result being a rapid, smooth, and homogeneous deposit.

2. The frictional contact derived from the bearing of the hooks carrying the work into the bath against the cathode bar, insures a keen, never failing, electric action to enter the bath. The contact points are always clean and sure.

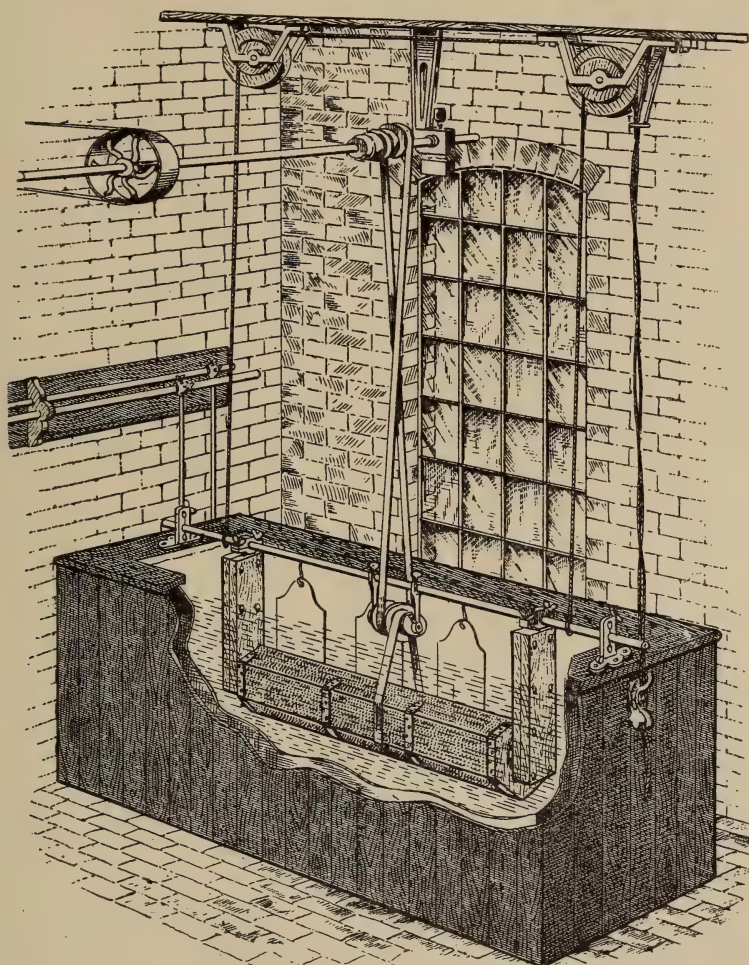
3. The movement through the bath passes the work in constantly changing positions before the anodes while undergoing the process of deposition.

4. To increase the movement of the work and vary the nature of the motion during its travel through the bath, small deflecting devices are introduced at desired distances along and upon the cathode bars, and for special work, revolving hooks have been used to great advantage.



5. The proximity of the work to the anode in the plating bath is well known to cause conditions favorable or unfavorable to the formation of a good deposit. Experiments have plainly

FIG. 109.



**APPARATUS AT WORK.**

shown, and the daily application of these devices proves, that the distance between the work and the anode can be consider



ably reduced and the intensity of the current increased without danger of burning the work when the latter is gently moved. By reducing distance between anode and cathode, the resistance upon the dynamo is accordingly diminished, and this condition is very desirable in nickel and other solutions which are of a neutral and non-conducting nature.

The Bossard tanks are quite expensive and not largely used.

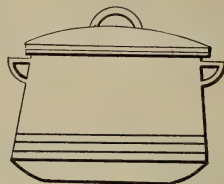
Fig. 109 shows the electrolytic plating apparatus for mechanical electro-plating patented by the Electrolytic Plating Apparatus Co., of Walsall and Birmingham, England.

This apparatus consists of a revolving barrel immersed in the plating solution. As the deposit takes place it is burnished down, giving the same protection that burnishing silver does, and dispenses with previous copper plating.

FIG. 110.



FIG. 111.



The machine here illustrated has been adopted by the largest manufacturers of metal goods in Great Britain, Germany, and France. It is believed that a large proportion of metal goods plated in the ordinary way can be done with this new process, the work coming out brightly polished, saving wiring, buffing, and the cost of materials, enabling a vast quantity of articles to be plated that, owing to the cost of handling, could not be done before.

The Hanson & Van Winkle Co. of Newark, N. J., have the sole agency for the United States and Canada of this apparatus.

The degree of temperature required for the electro-plating solutions has already been discussed on page 94, where also the means have been given by which too cool solutions may be brought to the proper degree of temperature. Baths which

are to be used cold should under no circumstances show a temperature below  $59^{\circ}$  F., it being best to maintain them at between  $64.5^{\circ}$  and  $68^{\circ}$  F.

Boiling is required in the preparation of many baths, if, after cooling, they are to yield good and certain results. The kettles and boiling-pans used for the purpose are of various shapes, hemispherical or with flat bottom, and are made of different materials (Figs. 110 and 111), those of enameled iron, or, for small baths, of porcelain or earthenware, being best. The enamel of the iron kettles must be of a composition which is not attacked by the bath. Notwithstanding their enamel these vessels become gradually impregnated with the solutions they have held, and it is dangerous to employ them for different kinds of baths. Thus, an enameled kettle which has been used for silvering will not be suitable, even after the most thorough washing, for a gold bath, as the gilding will certainly be white or green, according to the quantity of silver retained by the vessel. The use of metal vessels should be avoided. Copper and brass baths may, however, be boiled in strong copper kettles, though they are somewhat attacked. A copper kettle, after being freed from grease and scoured bright, may be provided with a thick deposit of nickel, by filling it with a nickel bath, connecting it with the negative pole of a strong battery or dynamo machine, and suspending in it a number of nickel anodes connected with the positive pole. Such nickeled kettle may be used for boiling nickel baths, but enameled kettles or large dishes of nickel-sheet, or vessels lined with lead, deserve the preference. Generally speaking nickel baths do not require actual boiling, but the nickel salts and certain conducting salts which constitute the baths, dissolve with difficulty in cold water and hence solution is effected in hot water.

When, for the preparation of nickel baths, nickel salts soluble with difficulty have to be dissolved with the assistance of heat and no suitable vessel is available for the purpose, solution may be effected as follows: Bring pure water in a bright

copper kettle to the boiling point. Pour the hot water into a clean wooden bucket holding from 8 to 10 quarts and add the quantity of nickel salt corresponding to the quantity of water. Stir with a wooden crutch until solution is complete. Repeat the operation until all the salt required is dissolved.

For very large baths this process would, however, require too much time, and it is, therefore, advisable to use a large round or oval wooden vat, or a vat lined with pure sheet lead. The contents of the vat are heated by means of a lead coil through which steam is introduced.

If the prepared and boiled solutions are not entirely clear, they have to be filtered, which for large baths is best effected with bags of fine felt; and for smaller baths, especially those of the noble metals, with filtering paper. It is still better to allow the baths to clarify by standing quietly and to draw off the clear solution by means of a siphon. The turbid residue is then filtered.

To secure *lasting qualities* to the bath, they must be carefully protected from every possible contamination. When not in use for plating they should be covered to keep out dust. The objects before being placed in the baths should be free from adhering scouring material or dipping fluid, which otherwise might, in time, spoil the bath. The cleansing of the anode and object rods by means of sand-paper, or emery-paper, should never be done over the bath, so as to avoid the danger of the latter being contaminated by the oxides of the metal constituting the rods falling into it. When a visible layer of dust has collected upon the bath, it must be removed, as otherwise particles of dust might deposit upon the articles and prevent an intimate union of the deposit with the basis-metal. With large baths the removal of the layer of dust is readily effected by drawing a large piece of filtering or tissue paper over the surface, and repeating the operation with fresh sheets of clean paper until all the dust is removed. Small baths should be filtered.

*The choice of anodes* is also an important factor for keeping

the baths in good condition, as well as for obtaining good results. The anodes should always consist of the metal which is deposited from the solution; and the metal used for them must be *pure* and free from all admixtures. To replace as much as possible the metal withdrawn from the bath by the electro-plating process, the anodes must be soluble; and it is wrong if, for instance, nickel baths are charged with insoluble anodes of carbon; or for smaller baths, of sheet platinum, provided the chemical composition of the bath does not in part demand insoluble anodes. Insoluble anodes cause a steady and rapid declination in the content of metal, an excessive formation of acid in the bath, and, by the detachment of particles of carbon, a contamination of the solution. Further particulars in regard to anodes will be given in discussing the separate baths.

When upon a pure metallic surface another metal is electro-deposited, the first portion of the deposit penetrates into the *basis-metal*, thus forming an alloy. This may be readily proved by repeating Gore's experiments: If a thick layer of copper be precipitated upon a platinum sheet, and then heated to a dark red heat, the deposit can be entirely peeled off. By then heating the platinum sheet with nitric acid, and thoroughly washing with water, it appears, after drying, entirely white and pure. By re-heating the sheet, the surface becomes again blackened by cupric oxide, and by frequently repeating the same operation a fresh film of cupric oxide will always be obtained.

This penetration of the deposit into the basis-metal, however, does not merely take place during electro-plating, but also later on; and it may frequently be observed that, for instance, zinc objects only slightly coppered or brassed, after some time become again white. Since this also happens when the deposits are protected by a coat of lacquer against atmospheric influences, the only explanation of the phenomenon can be that the deposit is absorbed by the basis-metal, which is also confirmed by analysis. This fact must be taken into consideration if durable deposits are to be produced.



To guarantee good performance an electro-plating bath must fulfil the following conditions:—

1. It must possess good working capacity.
2. It must exert a sufficient dissolving action upon the anode.
3. It must reduce the metal in abundance and in a reguline state.
4. It must not be chemically decomposed by the metals to be plated, hence not by simple immersion; the adherence of the deposit to the basis-metal being in this case impaired.
5. It must not be essentially decomposed by air and light.

*Reduction of metals without a battery (electro-deposition by contact).*

The reduction of metals which takes place by the *contact of two metals in one fluid* without the aid of an exterior source of current may here be appropriately mentioned. That an electric current is thereby generated has been previously explained. One metal, by coming in contact with a more electro-positive one, becomes electro-negative and decomposes the fluid. If the latter is a metallic solution, and the metal contained in it not more strongly electro-negative than the negatively excited metal, a separation of metal takes place in consequence of decomposition. *This process is termed electro-deposition by contact.* Generally the metals which are to be coated are brought in contact with a bright rod of zinc, the latter being a highly electro-positive metal. The zinc is allowed to dip in only so far as actually to secure a contact with the metal to be coated.

The contact of one metal with *two fluids* or that of *two metals in two fluids*, presents similar phenomena, an electric current with visible action manifesting itself, and in the latter case we have a complete element. By dipping the more electro-negative metal in a metallic solution whose metal is not more electro-negative, the metal separates from the solu-

tion upon the metallic strip dipping in. While by the contact of one metal with another in one fluid, only thin deposits can be produced, and by coating the electro-negative metal with the separated metal, the contact-current loses some of its original strength, by immersing two metals in two fluids, deposits of considerable thickness can under certain conditions be produced, as, for instance, with the galvano-plastic cell apparatus, which will be discussed later on.

A reduction of metal can also be brought about by dipping *one* metal into *one* fluid. This may take place in consequence of the simple solution of the metal dipped in, and hence the separation may be conceived as a simple chemical action. In how far electric currents manifest themselves and co-operate thereby is still undecided. It is only known that the electro-positive metals, such as zinc, tin, iron, copper, can reduce the electro-negative metals, such as mercury, silver, gold, etc., from the solutions of their salts, and that the reduction is the more rapid and the stronger the more electro-positive the metal dipped in is, and the more electro-negative the dissolved metal is.

Upon this action is based coppering, silvering, gilding, etc., by immersion.

## CHAPTER VII.

### DEPOSITION OF NICKEL AND COBALT.

#### I. NICKELING.

ALTHOUGH nickel-plating is of comparatively recent origin, it shall be first described, since chiefly by reason of the development of the dynamo-electrical machine it has steadily grown in popularity and become an industry of great magnitude and importance. The great popularity which nickel-plating enjoys is due to the excellent properties of the nickel itself: The almost silvery whiteness of the metal, its cheapness as compared with silver, and the hardness of the electro-deposited metal, which give the coating great power to resist wear and abrasion; its capability of taking a high polish; the fact that it is not blackened by the action of sulphurous vapors which rapidly tarnish silver, and finally the fact that it exhibits but little tendency to oxidize even in the presence of moisture.

*Properties of nickel.*—Pure nickel is a lustrous, silvery white metal with a slight steel-gray tinge. It is hard, malleable and ductile. Its specific gravity varies from 8.3 (cast nickel plates) to 9.3 (wrought or rolled plates). It melts at about the same temperature as iron, but is more fusible when combined with carbon. It is slightly magnetic at ordinary temperatures, but loses this property on heating to 680° F.

The metal is soluble in dilute nitric acid, concentrated nitric acid rendering it passive, *i. e.*, insoluble. In hydrochloric and sulphuric acids it dissolves very slowly, especially when in a compact state.

Certain articles, for instance hot fats, strongly attack nickel, while vinegar, beer, mustard, tea, and other infusions produce stains; hence, the nickeling of culinary utensils or the use of

nickel-plated sheet-iron for that purpose cannot be recommended.

The chemical equivalent of nickel is 29.5.

*Nickel baths.*—The first requisite in preparing nickel baths is the use of absolutely pure chemicals, and in choosing the nickel salts to be especially careful that they are free from salts of iron, copper, and other metals. Furthermore, it is not indifferent what kind of nickel salt is used, whether nickel chloride, nickel sulphate, the double sulphate of nickel and ammonium, etc., but the choice of the salt depends chiefly on the nature of the metal which is to be nickeled. There are a large number of general directions for nickel baths; of which nickel chloride, ammonio-nickel chloride, nickel nitrate, etc., form the active constituents, and yet it would be a grave mistake to use these salts for nickeling iron, because the liberated acid, if not immediately and completely fixed by the anodes in dissolving, imparts to the iron objects a great tendency to the formation of rust. Iron objects nickeled in such a bath, to be sure, come out faultless, but in a short time, even if stored in a dry place, portions of the nickel layer will be observed to peel off, and by closely examining them it will be seen that under the deposit a layer of rust has formed which actually tears the nickel off. The use of nickel sulphates or of the salts with organic acids is, therefore, considered best. It might be objected that the liberated sulphuric acid produces in like manner a formation of rust upon the iron objects; but according to long experience and many thorough examinations such is not the case, the tendency to the formation of rust being only imparted by the use of the chloride and nitrate. The use of nickel salts with organic acids is in many cases more advantageous than that of the sulphates, but such salts are far more expensive, and hence they are less frequently employed. In many *prepared nickeling salts* they form the active constituent. The composition of the *conducting salts* requires the same deliberation as that of the nickeling salts. To decrease the resistance of the nickel solutions, conducting salts are added to them, which are also par-



tially decomposed by the current. Like the use of nickel chloride in nickeling iron, an addition of ammonium chloride, which is much liked, cannot be recommended, though the subsequent easy deposition of nickel with a comparatively weak current invites its employment.

For copper and its alloys, zinc, etc., the chlorine combinations may be used, but for nickeling iron they must be avoided as the source of future evils. The use of sodium sulphide, sodium nitrate, barium oxalate, ammonium nitrate, sodium sulphate, and ammonia-alum as conducting salts, which has been recommended by various authors, is unsuitable and partly injurious. With few exceptions, which will be given later on, the best basis for the conducting salt, according to Böttger and Adams, is ammonia, especially in the form of ammonia sulphate or hydrochlorate, provided the latter is not used for baths for nickeling iron.

Some other additions to the nickeling bath which are claimed to effect a pure silver-white deposit have been recommended by various experts. Thus, the presence of small quantities of an organic acid has been proposed; for instance, boric acid by Weston, benzoic acid by Powell, and citric acid or acetic acid by others. The presence of small quantities of a *free acid* effects without doubt the reduction of a *whiter* nickel than is the case with a neutral or alkaline solution. Hence a *slightly* acid reaction of the nickeling bath, due to the presence of citric acid, etc., with the exclusion of the strong acids of the metalloids, can be highly recommended. The quantity of free acid, however, must not be too large, as this would cause the deposit to peel off.

*Boric acid*, recommended by Weston as an addition to nickeling and all other baths, has a favorable effect upon the pure white reduction of the nickel, especially in nickeling rough castings, *i. e.*, surfaces not ground. Weston claims that boric acid prevents the formation of basic nickel combinations on the objects, and that it makes the deposit of nickel more adherent, softer, and more flexible. Whether with a correct current-

strength, basic nickel salts, to which the yellowish tone of the nickeling is said to be due, are separated on the cathode, is not yet proved, and would seem more than doubtful. The action of the boric acid has not yet been scientifically explained, but numerous experiments have shown that the deposition of nickel from nickel solution containing boric acid is neither more adherent nor softer and more flexible than that from a solution containing small quantities of a free organic acid. Just the reverse, the deposition is harder and more brittle in the presence of boric acid, and different results may very likely be due to the employment of currents of varying strength. A *weak* current always and under all conditions causes the deposition of a *harder* and *more brittle* nickel than a current of medium strength; and in order to judge the quality of the deposited nickel from baths of varying composition, the surface of the objects and of the anodes must always be the same, and currents of equal quantity and electro-motive force be conducted into the bath. Weston's bath will be referred to later on. Powell's proposition for the use of benzoic acid need scarcely be taken seriously, since the results from baths containing it differ in no respect from those without it.

Before giving suitable formulæ for the composition of nickel baths, it will be necessary to discuss the means of determining their acidity and alkalinity. As previously mentioned, a nickel bath, to yield a beautiful white deposit, should contain only a small quantity of free acid. Too much acid prevents the firm adherence of the deposit, while alkaline and even neutral baths do not yield nickel of a pure white color, but of a somewhat darker tone. A bath is *neutral* when it contains neither free acid nor free alkali, which is recognized by neither blue nor red litmus paper\* being changed by the solution. Blue litmus-paper is colored red by acid liquids, and red litmus-paper blue by alkaline fluids. By simultaneously dipping one-half of a strip of blue and of red litmus-paper in the solution, the re-

\* Blue and red litmus-paper must be kept, each by itself, in well-closed glass jars.

action of the fluid can be judged from the change in color, and the rapidity and intensity of its appearance. If a bath which, like most nickel baths, is to work with only a slight reaction, immediately and intensely reddens blue litmus paper, a suitable alkali has to be added until the coloration of a fresh strip of litmus-paper appears more slowly and less intense. If, on the other hand, the test shows that red litmus-paper becomes blue, and that consequently the bath is alkaline, a slightly acid reaction is restored by the gradual addition of citric acid or another acid suitable to the composition of the bath. Baths made with boric acid form an exception, and must work with a strong acid reaction.

I. *The most simple nickel bath* consists of a solution of 8 to 10 parts by weight of pure nickel ammonium sulphate in 100 parts by weight of distilled water. If too acid, the solution is neutralized with spirits of sal ammoniac to a slightly acid reaction. The solution is prepared by boiling the salt with the corresponding quantity of water, using in summer 10 parts of nickel salt to 100 of water, but in winter only 8 parts, to prevent the nickel salt from crystallizing out. This bath, which is frequently used, possesses, however, a considerable degree of resistance to conduction, and hence requires a strong current for the deposition of the nickel. It also requires cast nickel anodes, since with the use of rolled anodes nickeling proceeds in a very sluggish manner. However, the cast anodes rapidly render the bath alkaline, necessitating a frequent correction of the reaction. To decrease the resistance, recourse has been had to certain *conducting salts*, and, below, the more common nickel baths will be discussed, together with their mode of preparation and action, as well as their availability for certain purposes.

II. Nickel ammonium sulphate 17 ozs., ammonium sulphate 17 ozs., distilled water 10 quarts.

Boil the salts with the water, and, if the solution is not too acid, restore its neutrality by spirits of sal ammoniac; then gradually add solution of citric acid until blue litmus-paper is

slowly but visibly reddened. The bath deposits rapidly, it possessing but little resistance. An electro-motive force of 1.8 to 2 volts suffices, and all metals (zinc, lead, tin, and Britannia, after previous coppering) can be nickeled in it. However, upon rough castings and iron a pure white deposit is difficult to obtain, frequent scratch-brushing with a medium hard steel brush being required. On account of the great content of sulphate of ammonium in the bath, the nickel deposit piles up especially on the lower portions of the objects, which, in consequence, readily become dull (*burn or over-nickel*, for which see later on), while the upper portions are not sufficiently nickeled. For this reason the objects must be frequently turned in the bath so that the lower portions come uppermost. This piling up of the deposit also frequently prevents the latter from acquiring a uniform thickness.

III. Nickel ammonium sulphate  $25\frac{1}{2}$  ozs., ammonium sulphate 8 ozs., crystallized citric acid  $1\frac{3}{4}$  ozs., water 10 to 12 quarts.

The bath is prepared in the same manner as the preceding, the salts being dissolved in boiling water, and ammonia added until blue litmus-paper is only slightly reddened.

This bath requires a somewhat greater electro-motive force than the preceding, or about 2 to 2.2 volts. The formation of the deposit is, however, more uniform, the nickeling of a beautiful white color, dense and hard and, consequently, when the deposit is thick enough, it will bear a high polish without danger of the nickel grinding off. This bath (III.) is very suitable for nickeling ground surgical instruments as well as every kind of ground iron articles which are to receive a thick and solid deposit. It is also well adapted for heavy nickeling of copper, brass, bronze, etc. This bath with or without the addition of citric acid was formerly in general use in this country. It requires, however, careful regulation of the current-strength to avoid peeling off, and to overcome this tendency to peeling off, it is advisable to decrease the content of ammonium sulphate. The bath should show only a very



slightly acid reaction, or should be neutral, and it is best to use an equal number of cast and rolled nickel anodes.

If, after working for some time, the nickeling becomes dark, an addition of nickel sulphate is advisable.

IV. Nickel ammonium sulphate 23 ozs., ammonium chloride (crystallized)  $11\frac{1}{2}$  ozs., water 10 to 12 quarts.

The bath is prepared in the same manner as given for II. and III. It nickels very rapidly and quite white, but the deposit is soft, and hence care must be had in polishing upon cloth or felt bobs, the corners and edges of the objects especially requiring careful handling. On account of the danger of peeling off, a heavy deposit of nickel cannot be obtained in this bath, since, in consequence of the rapid precipitation, the deposit condenses and absorbs hydrogen, is formed with a coarser structure, and turns out less uniform and dense. These phenomena are a hindrance to a heavy deposit, which, if it is to adhere, must be homogeneous and dense. As previously mentioned, *baths with the addition of chlorides as well as those prepared with nickel chloride and nickel nitrate are not suitable for the solid nickeling of iron.* They are, however, well adapted to the rapid light nickeling of *cheap brass articles.* The electromotive force required for this bath is 1.8 volts.

V. Nickel chloride (crystallized)  $17\frac{1}{2}$  ozs., ammonium chloride (crystallized)  $17\frac{1}{2}$  ozs., water 12 to 15 quarts.

This bath is prepared by dissolving the salts in lukewarm water and adding spirit of sal ammoniac until the bath shows a very slightly acid, or a neutral, reaction. The bath deposits readily and is especially liked for nickeling zinc castings. Tension of current 1.5 to 1.75 volts; for zinc higher.

VI. *Baths containing boric acid.* Weston recommends the following composition for nickel baths: Nickel chloride  $17\frac{1}{2}$  ozs., boric acid 7 ozs., water 20 quarts; *or* nickel-ammonium sulphate 35 ozs., boric acid  $17\frac{1}{2}$  ozs., water 25 to 30 quarts. Both solutions are said to be improved by adding caustic potash or caustic soda so long as the precipitate formed by the addition dissolves.

These compositions, however, cannot be recommended, because the baths work faultlessly for a comparatively short time only. All kinds of disturbing phenomena very soon make their appearance, the deposit being no longer white but blackish, and the baths soon failing entirely. Kaselowsky's formula yields similar results. This bath is prepared by dissolving, with the assistance of heat,  $35\frac{1}{4}$  ozs. of nickel ammonium sulphate and  $17\frac{3}{8}$  ozs. of boric acid in 20 quarts of water. This bath also generally fails after two or three months' use. The cause of this has to be primarily sought for in the fact that baths prepared with boric acid require according to their composition a definite proportion between rolled and cast nickel anodes. If rolled anodes are exclusively used, free sulphuric acid is soon formed, which causes energetic evolution of hydrogen on the articles, but prevents a vigorous deposit and imparts to the latter a tendency to peel off. The same thing happens when a nickel salt not entirely neutral has been used in the preparation of the bath. If, on the other hand, cast nickel anodes alone are employed, the bath soon becomes alkaline, with turbidity and the formation of slime, and the deposit turns out gray and dull before it possesses sufficient thickness.

From the foregoing it will be readily understood that the nickel salt used must be neutral and that the proportion of rolled to cast anodes must be so chosen that the free sulphuric acid formed on the cast anodes is neutralized, but that the acidity of the bath dependent on the free boric acid is constantly maintained.

Such a bath containing boric acid may advantageously be prepared as follows:

VII. Nickel-ammonium sulphate 21 ozs., chemically pure nickel carbonate  $1\frac{3}{4}$  ozs., chemically pure boric acid (crystallized)  $10\frac{1}{2}$  ozs., water 10 to 12 quarts.

Boil the nickel-ammonium sulphate and the nickel carbonate in the water until the evolution of bubbles of carbonic acid ceases and blue litmus-paper is no longer reddened. After allowing sufficient time for settling, decant the solution from

any undissolved nickel carbonate and add the boric acid. Boil the whole a few minutes longer, and allow to cool. If the nickel salt contains no free acid, boiling with the nickel carbonate may be omitted. The solution shows a *strongly acid* reaction, which must not be removed by alkaline additions.

The proportion of cast to rolled anodes used in this bath is dependent on the quality of the anodes. The use of readily soluble cast anodes requires the suspension in the bath of more rolled anodes than when cast anodes dissolving with difficulty are employed, since the surfaces of the latter, in consequence of rapid cooling, are not readily attacked. The proportion has likewise to be changed, with the use of soft or hard-rolled anodes. Hence the proper proportion will have to be established by frequently testing the reaction of the bath. For this purpose the following rules may be laid down: Blue litmus-paper must always be perceptibly and intensely reddened, but congo-paper should not change its red color, for if the latter turns blue it is an indication of the presence of free sulphuric acid in the bath, which has to be neutralized by the careful addition of solution of soda or potash until a fresh piece of congo-paper dipped in the bath remains red. Ammonia cannot be recommended for neutralizing free sulphuric acid in this bath. Red litmus-paper must remain red, for if it turns blue, the bath has become alkaline and fresh boric acid has to be dissolved in the previously heated bath until a fresh piece of blue litmus paper acquires an intense red color.

The bath prepared according to the above formula (VII) requires an electro-motive force of about 2.3 to 2.5 volts.

Below are given a few other formulæ for nickel baths which may be advantageously used for *special purposes*, but not for nickeling all kinds of metals with equally good results.

VIII. Nickel sulphate  $10\frac{1}{2}$  ozs., potassium citrate 7 ozs., ammonium chloride 7 ozs., water 10 to 12 quarts.

To prepare the bath dissolve  $10\frac{1}{2}$  ounces of nickel sulphate and  $3\frac{1}{2}$  ounces of pure crystallized citric acid in the water; neutralize accurately with caustic potash, and then add the

ammonium chloride. This bath is especially adapted for the rapid nickeling of *polished, slightly coppered zinc* articles. Deposition is effected with a very feeble current, without the formation of black streaks, such as are otherwise apt to appear in nickeling with a weak current. The deposit itself is dull and somewhat gray, but acquires a very fine polish and pure white color by slight manipulation upon the polishing wheels. With a stronger current the bath is also suitable for the direct nickeling of zinc articles; it must, however, be kept strictly neutral. The bath works with rolled anodes, and but seldom requires a correction of the reaction.

IX. Nickel phosphate  $8\frac{1}{2}$  ozs., sodium pyrophosphate  $26\frac{1}{4}$  ozs., water 10 to 15 quarts. Dissolve the sodium pyrophosphate in the water, heat the solution to about  $167^{\circ}$  F. and add the nickel phosphate with constant stirring. Nickel phosphate is obtained as a pale green powder by precipitating solution of nickel sulphate with sodium phosphate.

This bath yields a very fine dark nickeling upon *iron, brass, and copper*, as well as *directly*, without previous coppering, upon *sheet zinc* and *zinc castings*, and may be advantageously used for decorative purposes where darker tones of nickel are demanded.

For nickeling of a dark tone, Pfanhauser recommends a bath quite poor in nickel, showing an ammoniacal or alkaline reaction. A weak current should be employed and very small rolled nickel anodes. He gives the following solutions as suitable for the purpose: Water 1 quart, nickel-ammonium sulphate 0.35 oz., spirits of sal ammoniac  $1\frac{3}{4}$  ozs.; *or*: Water 1 quart, nickel-ammonium sulphate 0.35 oz., sodium hyposulphate  $1\frac{3}{4}$  ozs., spirits of sal ammoniac  $1\frac{3}{4}$  ozs.

X. A fairly good nickel-bath for electro-platers having but a feeble current at their disposal is obtained from a solution of nickel-ammonium sulphate  $22\frac{1}{2}$  ozs., magnesium sulphate  $11\frac{1}{4}$  ozs., water 10 to 12 quarts.

This bath precipitates readily and strongly, and a heavy coating can also be deposited upon *iron* without fear of the



disagreeable consequences of bath IV. Even *zinc* may be directly nickeled in it with a comparatively feeble current. The deposit, however, turns out rather soft, with a yellowish tinge, and the bath does not remain constant, but fails after working at the utmost three or four months, the anodes being scarcely attacked.

Below are given the compositions of a few nickel baths which have been highly recommended:—

XI. Pure nickel sulphate  $35\frac{1}{2}$  ozs., neutral ammonium tartrate  $26\frac{1}{2}$  ozs., tannin 77 grains, water 20 quarts. Neutral ammonium tartrate is obtained by saturating a solution of tartaric acid with ammonia. The nickel salt must also be neutral. For this purpose dissolve the above-mentioned ingredients in 3 or 4 quarts of water and boil the solution for  $\frac{1}{4}$  hour, then add enough water to make 20 quarts of fluid, and filter. The bath is said to yield a very white, soft, and homogeneous deposit of any desired thickness, without roughness or danger of peeling off. On rough or polished castings thick deposits may be obtained at a cost scarcely exceeding that of coppering. Galvano-plastic reproduction may also be effected in this bath. For those who wish to try the bath it may be mentioned that the most suitable current-strength is 3.5 volts.

XII. An English formula is as follows: Dissolve  $17\frac{1}{2}$  ozs. of nickel sulphate,  $9\frac{1}{4}$  ozs. of tartaric acid, and  $2\frac{1}{4}$  ozs. of caustic potash in 10 quarts of water.

The addition of bisulphide of carbon to nickel baths, which has been recommended by Bruce, is not advisable. According to Bruce, such an addition prevents the nickel deposit from becoming dull when reaching a certain thickness, but repeated experiments made strictly in accordance with the directions given did not confirm this statement.

XIII. For nickeling small articles the following bath is claimed to yield excellent results: Nickel-ammonium sulphate 64 ozs., ammonium sulphate  $20\frac{1}{4}$  ozs., crystallized citric acid  $4\frac{1}{2}$  ozs.

For the production of very thick deposits, the following bath

has been recommended: Nickel sulphate 16 ozs., sodium citrate 10 ozs., water 10 quarts. This bath is said to be especially useful in preparing nickel clichés. However, numerous experiments proved it to possess the disadvantages of all nickel baths prepared with large quantities of organic combinations, and for the special purpose for which it is recommended no better results were obtained than with any other nickel bath rationally composed for heavy deposits.

Some authors have recommended for nickeling a solution of nickel cyanide in potassium cyanide, but experiments failed to obtain a proper deposition of nickel.

The general remark may here be added that *freshly prepared* nickel baths mostly work correctly from the start, though it may sometimes happen that the articles first nickeled come from the bath with a somewhat darker tone. In such case it is advisable to suspend a few anodes to the cathode and allow the bath to work one or two hours, when nickeling will proceed faultlessly. If, however, such should not be the case, test the specific gravity of the bath with the hydrometer. The standard specific gravity is 6° to 7° Bé., and if the bath shows a greater specific gravity dilute it to 7° Bé. If after dilution the deposit is not of a light color, the nickel salt very likely contains traces of copper.

It has further been observed that freshly prepared baths deposit a somewhat more brittle nickel, and that the deposit shows a tendency towards peeling off. The cause of this phenomenon is not thoroughly understood, but perhaps it is due to an increased occlusion of hydrogen. When this phenomenon is observed it is advisable very carefully to free the articles from grease and clean them, and during the first days not to force the thickness of nickeling too far. If peeling off is nevertheless observed, even when the reactions of the bath are correct, allow the bath to work for some time in the manner described above. Older baths yield very flexible deposits and are less sensitive towards an incorrect current.

It may also be mentioned that peeling off is frequently

observed when additions for the purpose of neutralization have been made to nickel baths. This phenomenon disappears in a few days, but it demonstrates that, instead of correcting the reaction of the bath by the addition of acids or alkalis, it should be done by increasing the rolled anodes in case the bath has a tendency to become alkaline, or to increase the cast anodes in case the bath becomes too acid.

A few words may here be said in regard to what may be termed a *nickel bath without nickel salt*. It simply consists of a 15 to 20 per cent. solution of ammonium chloride, which transfers the nickel from the anodes to the articles. Cast anodes are almost exclusively used for the purpose, and deposition may be effected with quite a feeble current. Before the solution acquires the capacity of depositing, quite a strong current has to be conducted through the bath until the commencement of a proper reduction of nickel. This bath is only suitable for *coloring* very cheap articles, it not being possible to produce solid nickeling with it. It is here mentioned because it may serve as a representative of a series of other electroplating baths in which the transfer of the metal is effected by sal ammoniac solution without the use of metallic salts, for instance, iron, zinc, cobalt, etc.

The heating of nickel baths, which is in favor with some platers, may here be referred to. In a heated bath the deposit forms more rapidly in consequence of the slighter resistance, and because less current-tension is required. However, by reason of general complaints that deposits effected in a heated bath peel off, the use of such a bath for nickeling would not appear advisable.

*Nickel anodes.*—Either *cast* or *rolled* nickel plates are used as anodes, which must of course be as pure as it is possible to obtain them. Every impurity of the anodes passes into the bath and jeopardizes its successful working. If too thin the anodes increase the resistance. For small baths rolled anodes 0.079 inch thick are generally used, and as a rule they should not be less than 0.039 inch thick. For larger baths it is better to use

plates from 0.11 to 0.19 inch thick, while the thickness of cast anodes may vary between 0.11 and 0.39 inch, according to the size of the bath and the purpose for which it is to be used. The use of *insoluble* anodes of gas-carbon or platinum, either by themselves or in conjunction with nickel anodes, as frequently recommended, is not advisable. The harder and the less porous the nickel anode is, the less it is attacked in the bath and the less it fulfils the object of keeping constant the metallic content of the solution. On the other hand, the softer and the more porous the anode is, the more readily it dissolves, because it conducts the current better and presents more points of attack to the bath; and the more it is dissolved, the more metal is conveyed to the bath. With the sole use of rolled anodes and working with a feeble current, free acid is formed in the bath; on the other hand, by working with cast anodes alone, the bath readily becomes alkaline. Now it would appear that the possibility of a bath also becoming alkaline even with the sole use of rolled anodes, especially when working with a strong current, has led to the proposal of suspending in the bath, besides the nickel anodes, a sufficient number of insoluble anodes in order to effect a constant neutrality of the bath. It would lead too far to go into the theory of the secondary decompositions which take place in a nickel bath, to prove that, though neutrality is obtained, it can only be done at the expense of the metallic content of the bath. Hence, this impracticable proposal shall here be overthrown by practical reasons, it only requiring to be demonstrated that in baths becoming alkaline the content of nickel also decreases steadily though slowly. This fact in itself shows that in order to save the occasional slight labor of neutralizing the bath, the decrease of the metallic content should not be accelerated by the use of insoluble anodes. For larger baths the use of expensive platinum anodes as insoluble anodes need not be taken into consideration, because for large surfaces of objects correspondingly large surfaces of platinum anodes would have to be present, as otherwise the resistance of thin platinum sheets would be con-



siderable. But such an expensive arrangement would be justifiable only if actual advantages were obtained, which is not the case, because, though the platinum does absolutely not dissolve, the deficiency of metallic nickel in the bath caused by such anodes must in some manner be replaced. The insoluble anodes of *gas-carbon*, which have frequently been proposed, are attacked by the bath. Particles of carbon become constantly detached, and floating upon the bath, deposit themselves upon the objects and cause the layer of nickel to peel off. Furthermore, by the use of nickel anodes in conjunction with carbon anodes, the current, on account of the greater resistance of the latter, is forced to preferably take its course through the metallic anodes, in consequence of which the articles opposite the nickel anodes are more thickly nickeled than those under the influence of the carbon anodes. With larger objects this inequality in the thickness of the deposit is again a hindrance to obtaining layers of good and uniform thickness, such as are required for solid nickeling. Since the current preferably seeks its compensation through these separate metallic anodes, they are more vigorously attacked than when nickel plates only are suspended in the bath.

With nickel baths which contain a considerable amount of ammonium chloride, the use of a few carbon anodes along with the rolled nickel anodes may be permissible, since these baths strongly attack even the rolled anodes, and thereby convey to the bath sufficient quantities of fresh nickel. Such baths containing ammonium chloride, as a rule, become very rapidly alkaline, so that frequent neutralization becomes inconvenient. However, in this case, it is advisable to place the carbon anodes in small linen bags which retain any particles of carbon becoming detached, the latter being thus prevented from depositing upon the articles in the bath.

According to long practical experience, the best plan is to use *rolled and cast* anodes together in a bath. The proportion of cast to rolled anodes depends on the composition of the bath, but it may be laid down as a rule, that baths with greater

resistance require more cast anodes, and baths with less resistance more rolled anodes. The proper proportion has been established when, after working for some time, the original reaction of the bath remains as constant as possible. When the bath is observed to become alkaline the number of rolled anodes should be increased, but when the content of acid increases they should be decreased, and the number of cast anodes increased.

Cast anodes, to be sure, have the disadvantage of becoming brittle, and crumbling before they are entirely consumed. Nickel anodes cast in iron moulds are so hard on their surfaces as to resist the action of the bath, and dissolve only with difficulty, so that the content of metal of the bath is only incompletely replenished. Anodes cast in sand moulds, and slowly cooled, are porous and consequently dissolve readily, but by reason of their porosity their interior portions are also attacked. If such an anode be broken, it will be found that the interior contains a black powder (nickel oxide) which novices sometimes believe to be carbon. In fact cases have been heard of that customers have complained that the anodes furnished them were not nickel anodes at all, but simply carbon plates coated with a layer of nickel.

The cast anodes suspended to the ends of the conducting rods are especially strongly attacked, and, therefore, when rolled and cast anodes are used together, it is best to suspend the latter more towards the centre, and the former on the ends of the rods.

These disadvantages, however, are not sufficient to prevent the use of a combination of cast and rolled anodes when required by the composition of the bath. The brittle remnants are thoroughly washed in hot water, dried and sold.

The *rolled nickel anodes* are less liable to corrosion, and may be used up to the thickness of a sheet of paper before they fall to pieces. It is, however, best to replace them by fresh anodes before they become too thin, since with the decrease in thickness their resistance increases.

The surface of the anodes suspended in the baths should be *at least* as large as that of the articles to be nickeled. It is, however, preferable that they should present twice or three times the surface, so that the bath may be kept thoroughly saturated with nickel.

It is best to allow the anodes to remain quietly in the bath, even when the latter is not in use, they being in this case not attacked. By frequently removing and replacing them they are subject to concussion, in consequence of which they crumble much more quickly than when remaining quietly in the bath.

In the morning, before nickeling is commenced, the anodes will frequently show a *reddish* tinge, which is generally ascribed to a content of copper in the bath or in the anodes. This reddish coloration also appears when an analysis shows the anodes as well as the bath to be absolutely free from copper. It is very likely due to a small content of cobalt, from which nickel anodes can never be entirely freed. It would seem that by the action of a feeble current cobaltous hydrate is formed, which, however, immediately disappears on conducting a strong current through the bath.

The anodes are supported by nickel wire 0.11 to 0.19 inch thick, or by strips of nickel sheet riveted on.

If after working for some time a nickel bath has become alkaline, which can be readily determined by testing with litmus-paper, its neutrality or a slightly acid reaction can in a few minutes be restored by the addition of either citric, sulphuric, acetic, or boric acid, according to the composition of the bath. On the other hand, when the bath contains too much free acid, it is removed by the addition of spirits of sal ammoniac, ammonium carbonate, potash, or by boiling with nickel carbonate, the choice of the remedy depending on the composition of the bath.

*Process of nickeling.*—Next to the correct composition of the bath and the proper selection of the anodes, the success of the nickeling process depends on the articles having been carefully

freed from grease and cleansed, and on the correct current-strength.

The directions for the removal of grease, etc., given on p. 169, also apply to objects to be nickeled. In executing the operations, it should always be borne in mind that though dirty, greasy parts become coated with nickel, the deposit immediately peels off by polishing, because an intimate union of the deposit with the basis-metal is effected with only perfectly clean surfaces. Touching the cleansed articles with the *dry* hand must be strictly avoided; but, if large and heavy objects have to be handled, the hands should first be freed from grease by brushing with lime and rinsing in water, and be kept wet.

As previously mentioned, the cleansed objects must not be exposed to the air, but immediately placed in the bath, or, if this is not practicable, be kept under clean water.

While copper and its alloys (brass, bronze, tombac, German silver, etc.), as well as iron and steel, are directly nickeled, zinc, tin, Britannia and lead are generally first coppered or brassed. With a suitable composition of the nickel bath and some experience, the last-mentioned metals may also be directly nickeled; but, as a rule, previous coppering or brassing is preferable, the certainty and beauty of the result being thereby considerably enhanced.

By many operators it is preferred to copper iron and steel articles before nickeling, it being claimed that by so doing better protection against rust is secured. However, comparative experiments have shown that with the thin coat of copper which, as a rule, is applied, this claim is scarcely tenable, and the conclusion has been reached that a thick deposit of nickel obtained from a bath of suitable composition protects the iron from rust just as well and as long as if it had previously been slightly coppered. It cannot be denied that previous coppering of iron articles has the advantage, that in case the articles have not been thoroughly cleansed, the deposit of nickel is less liable to peel off, because the alkaline copper bath completes the removal of grease; but with objects carefully cleansed ac-



cording to the directions given on p. 169, previous coppering is not necessary.

The case, however, is different if the copper deposit is produced in order to act as a cementing agent for two nickel deposits. If, for instance, parts which have previously been nickeled and from which the old deposit cannot be removed by mechanical means, are to be re-nickeled, coppering is required, because the new deposit of nickel adheres very badly to the old. Where articles are to be protected as much as possible from rust, coppering is advisable, but the best success is attained by a method different from the one generally pursued. In nickeling, for instance, parts of bicycles which are exposed to all kinds of atmospheric influences, they are first provided with a thick deposit of nickel, then with a thick coat of copper, and finally, again nickeled, they thus being twice nickeled. It has previously been mentioned that every deposit is formed net-like, the meshes of the net being larger or smaller, according to the nature of the metal deposited. If now thick layers of two different metals are deposited one on the top of the other, the net-lines of one deposit do not converge into those of the previous deposit, but are deposited between them, thus consolidating the net. It will now be readily understood that by the subsequent polishing the further consolidation of the deposits will be far more complete than when the basis-metal receives but one deposit, which is to be consolidated by polishing. It is a remarkable fact that the porosity of the nickel-deposit varies if the article is nickeled in several baths of different composition. Thus denser deposits may be obtained by suspending the articles in two or three baths, which proves that the different resistances of the respective baths of one and the same metal exert an influence upon the greater or slighter density of the net.

*The objects should never be suspended in the bath without current*, since the baths, with few exceptions, exert a chemical action upon many metals which is injurious to the electro-plating process, and especially with nickel baths it is necessary to con-

nect the anode-rods and object-rods before suspending the articles.

The *suitable current-strength* has already been fully discussed on p. 97 *et seq.* ("Electro-plating Arrangements in Particular"), and referring the reader to that section we may here be comparatively brief.

In that section it has been said that the surfaces of objects to be nickeled must be in due proportion to the effective zinc surface of the battery if the latter be used for generating the current; further, the surface of anodes suspended in the bath must be at least equal to that of the objects, though in most cases it is better that it should be larger. On p. 97 *et seq.*, it has also been explained how, according to circumstances, the elements have to be coupled to a battery in order to be sure of success. Two Bunsen elements, coupled one after the other, yield for nearly all nickel baths the electro motive force required for the reduction of the nickel. For baths with great resistance it will, however, be better, especially when the filling of the elements is no longer fresh, to couple three elements, one after the other, and to neutralize a momentary excess of current by the resistance-board.

An error is frequently committed in nickeling with too strong a current, the consequence being that the deposit on the lower portions of the objects soon becomes dull and gray-black, while the upper portions are not sufficiently nickeled. This phenomenon, which is due to the reduction of the nickel with a coarse grain in consequence of too powerful a current, is called *burning* or *over-nickeling*. A further consequence of nickeling with too strong a current is that the deposit readily peels off after it reaches a certain thickness. The phenomenon is due to the hydrogen being condensed and retained by the deposit, which is thereby prevented from acquiring greater thickness.

Especially do those objects suspended on the ends of the rods nickel with great ease. This evil can be avoided by hanging on both ends of the rods a strip of copper-sheet about 0.39

inch wide, and of a length corresponding to the depth of the bath.

The following criteria may serve for judging whether the nickeling progresses with a correct current-strength: In two or at the utmost three minutes all portions of the objects must be perceptibly coated with nickel, but without a violent evolution of gas on the objects. Small gas bubbles rising without violence and with a certain regularity are an indication of the operation progressing with regularity. If, after two or three minutes, the objects show no deposit, the current is too *weak*, and in most cases the objects will have acquired dark, discolored tones. In such case either a stronger current must be introduced by means of the resistance board, or, if the entire volume of current generated already passes into the bath, the object-surface has to be diminished, or, if this is not desired, the battery must be strengthened by adding more elements, or by fresh filling, etc.

If, on the other hand, a violent evolution of gas appears on the objects, and the latter are well covered in a few seconds, and the at first white and lustrous nickeling changes in a few minutes to a dull gray, the current is *too strong*, and must be weakened either by the resistance board, or uncoupling a few elements, or diminishing the anode-surface, or finally by suspending more objects in the bath.

These criteria also apply to nickeling with the dynamo.

The density of current most suitable for nickeling copper, copper-alloys, iron and steel is 0.6 ampère per 15.5 square inches, while zinc previously coppered requires 1.2 ampères.

It will be seen that in nickeling zinc objects greater density of current and higher tension are required. If the current is not of sufficient strength, black streaks and stains are formed, zinc is dissolved and the nickel bath spoiled. These evils are frequently complained of by nickel-platers who have not a clear perception of the prevailing conditions (see polarizing current). A vigorous evolution of gas must take place on the zinc objects, otherwise a serviceable deposit will not be obtained.

In most cases the electro-plater will in a few days learn correctly to judge the proper current-strength by the phenomena presented by the objects, and if he closely follows the directions given but few failures will result. It may here be again repeated that the use of a voltmeter as well as of a resistance board greatly facilitates a correct estimate of the proper current-strength, and these instruments should for the sake of economy never be omitted in fitting up an electro-plating plant.

It is in every case advisable first to cover the objects, *i. e.*, to effect the first deposit of nickel, with the use of a strong current, in order to withdraw the metals from the action of the solution. The current is then reduced to a suitable strength and nickeling finished with this current. With a current thus regulated, the objects may be allowed to remain in the bath for hours and even for days. It is further possible to nickel by weight and attain deposits of considerable thickness.

If very thick deposits of nickel are desired, the objects must be frequently turned in the bath, as the lower portions nickel stronger than the upper; further, as soon as the deposit acquires a dull bluish lustre it has to be thoroughly scratch-brushed, in doing which, however, the objects must not be allowed to become dry. After scratch-brushing it is advisable to cleanse the deposit once more with the lime-brush, and after rinsing replace the objects in the bath. If burnt places cannot be brightened and smoothed with the scratch-brush, the desired end is readily attained with the assistance of emery paper or pumice.

For *solid* nickeling it suffices in most cases to allow the objects to remain in the bath until a dull bluish lustre appears, this being an indication that the deposit has acquired considerable thickness, and will not take a further regular deposit. If such objects are permitted to remain longer in the bath without scratch-brushing, the dull bluish tone soon passes into a dull gray, and all the metal deposited in this form must be polished away in order to obtain a bright lustre.



Whether the deposit of nickel is sufficiently heavy for all ordinary demands is, according to Fontaine, shown by rubbing a nickeled corner or edge of the object rapidly and with energetic pressure upon a piece of planed soft wood until it becomes hot. The nickeling should bear this friction. This test can be recommended as perfectly reliable.

If the objects, after having been suspended for some time in the bath, are only partially nickeled, it is very likely due to the defective arrangement of the anodes. This occurs chiefly with large round objects and with articles having deep depressions (cups, vases, etc.).

For flat objects it is sufficient to suspend them between two rows of anodes. Round objects with a large diameter should be quite surrounded with anodes, and be as nearly as possible equi-distant from them. This arrangement should especially not be neglected where a heavy and uniform deposit of nickel is to be given to round or half-round surfaces—for instance, large half-round stereotype plates for revolving presses.

The arrangement of two object rods between two anode-rods is permissible only for small and thin articles such as safety-pins, crochet needles, lead-pencil holders, etc. For articles with larger surfaces it is decidedly objectionable, because the sides of the articles turned towards the anodes acquire a thicker deposit than the inside surfaces, and the thickness of the deposit decreases with the distance from the anodes.

While for smooth articles the most suitable distance of the anodes from the object is  $3\frac{3}{4}$  to  $5\frac{3}{4}$  inches, for objects with depressions and hollows it must be larger, if it is not preferred to make use of the methods described later on. However, a deposit of a uniform thickness cannot be obtained by this means, because the portions nearer to the anodes will acquire a thicker deposit than the hollows; hence the use of a small hand anode, which is connected by means of a thin flexible wire with the anode-rod, and introduced into the depressions and hollows, is to be preferred. This, of course, renders it necessary for a workman to stand alongside the bath and ex-

ecute the operation by hand; but as the small anode can be brought within a few millimetres of the surface of the article, and at this distance slowly moved around it, a correspondingly thick deposit is in a short time formed.

At any rate baths in which objects with depressions and hollows are to be nickeled must possess greater resistance than baths for nickeling flat articles, and it is inexplicable why a bath with a large content of ammonium chloride and consequently slight conducting resistance can be recommended, as has been done, for nickeling hollow articles.

In nickeling lamp-feet of cast-zinc, the use of the hand-anode can scarcely be avoided if the depressed portions also are to be provided with a uniformly good deposit. Moreover, zinc articles form an exception to the general rule in so far as by reason of the highly positive properties of zinc, the resistance of the bath may be slighter than for baths for nickeling copper and its alloys, as well as iron and steel.

Besides the above-mentioned general rules for nickeling, which also hold good for other electro-plating processes, the following may be given:—

In suspending the objects in the bath, rub the metallic hooks or wires, with which they are secured to the rods, a few times to and fro upon the rod, in order to be sure that the place of contact is purely metallic. It is also well to acquire the habit of striking the rod a gentle blow with the finger every time when suspending an object, the gas-bubbles settling on the articles becoming thereby detached and rising to the surface. It is further advisable, before securing the objects to the object-rod, several times to move them up and down; so to say, shake them beneath the fluid, whereby, on the one hand, the layers poorer in metal are mixed with those richer in metal, and, on the other, any dust which may float upon the bath and settle on the objects is removed.

The objects suspended in the bath should not touch one another, nor one surface cover another, and thus withdraw it from the direct action of the anode. In the first case stains

will readily form on the places of contact, and in the latter the covered surface acquires only a slight deposit. That the objects must not touch the anodes need scarcely be mentioned.

Objects with depressions and hollows should be suspended in the bath so that the air in the hollows can escape, which is effected by turning the depressions upwards, or, if there are several depressions on opposite sides, by turning the articles about after being introduced into the bath. Air-bubbles remaining in the hollows prevent contact with the solution, no deposit being formed on such places.

It remains to say a few words in regard to the so-called polarizing phenomena. In the theoretical part, it has been shown that by dipping two plates of different metals in a fluid a *counter* or *polarizing current* is generated, which is the stronger the further the two metals are removed from one another in the series of electro-motive force, and the more they differ in their electrical behavior. If the anodes in a nickel bath are of nickel and the articles of copper, the counter-current will be slight, because copper and nickel stand together in the series of electro-motive force (p. 15). The counter-current, however, becomes greater when iron objects are hung in the bath, and greatest with zinc surfaces which are to be nickeled, because zinc, being the most electro-positive metal, differs widely in its behavior from nickel. Now, since the counter-current flows in a direction opposite to that of the current introduced in the bath, the latter is weakened, and the more so the stronger the counter-current is. This explains why iron requires a stronger current for nickeling than copper-alloys, and zinc a stronger one than iron.

Now it may happen that the counter-current becomes so strong as to entirely annul the effect of the principal current, and even to reverse the latter, the consequence being that, in the first case, the formation of the deposit is interrupted, and, in the latter, that the deposit is again destroyed, and the metals of which the articles consist dissolve and contaminate and spoil the bath. To avoid this, a main current must be conducted

into the bath, which, by its sufficiently large electro-motive force, can overcome the counter-current, and the consequences of the reversion of the current can be prevented by using the galvanometer and observing the deflection of its needle, which (according to p. 103) in proper time indicates the appearance of a reversed current. Now if a nickel-plater has only a slight current at his disposal, it follows from the above explanation that before nickeling the more electro-positive metals, such as iron, tin, zinc, it is best first to copper them, and thereby annul the action of these metallic surfaces as regards the formation of the counter-current.

It happens comparatively seldom that the counter-current becomes so strong as to destroy the deposits formed, because for nickeling powerful Bunsen elements with two acids, or dynamo-electric machines with at least 4 volts' tension, are generally used. It is, however, well to acquaint the operator with all possible contingencies, and to explain the reason why the articles are preferably covered with a strong current. Sprague recommends an initial current of 5 volts tension, but in most cases one of 3.5 volts suffices for nickeling iron and copper alloys.

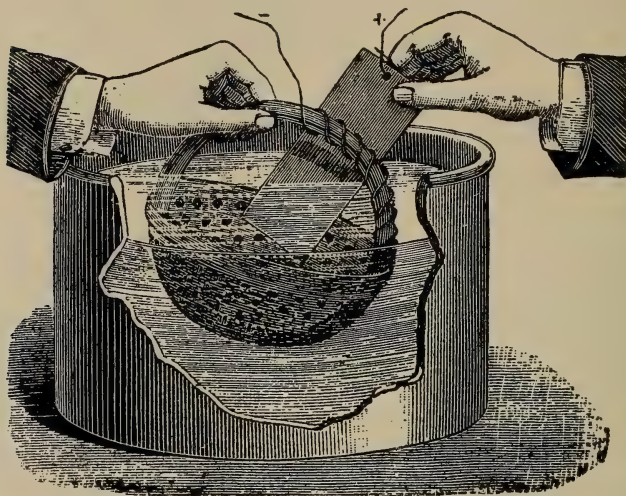
*Nickeling en masse of small and cheap objects.*—This is effected by stringing the objects, if feasible, upon a copper wire, and placing a large glass bead between every two objects, to prevent the surfaces from sticking together in the bath. Such objects being generally only slightly nickeled, it suffices to allow them to remain for a few minutes only in the bath with a strong current, it being advisable to diligently shake the bundles in order to effect a change of position of the objects and prevent their touching one another, notwithstanding the glass bead placed between them.

Very small objects, such as rivets, pins, etc., which cannot be strung upon wire, are nickeled in a stoneware dipping basket. To the bottom of the dipping basket is secured a copper or brass wire, which is connected with the object-rod, and the articles, not too many at a time, are then placed in the basket.



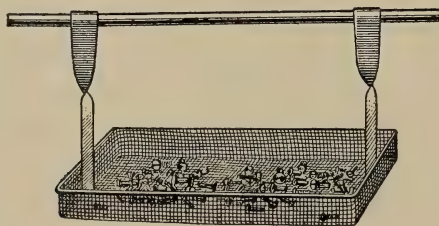
During the operation the articles must be constantly shaken, and as nickel baths, as a rule, do not conduct sufficiently well to properly nickel the objects in the basket, it is advisable to hold with one hand an anode connected by a flexible wire with

FIG. 112.



the anode-rod in the basket, while the other hand holds the sieve (Fig. 112) and constantly shakes and turns it. For nickeling in the dipping basket it is further advisable to heat the nickel bath.

FIG. 113.



In place of a stoneware dipping basket, a small shallow basket of brass wire, Fig. 113, to which are soldered two copper wires for suspending it to the object-rod, may preferably be

used. From the soldered places a few copper wires extend to the bottom of the basket. To prevent the basket from becoming covered with nickel it is coated with asphalt varnish. At a distance of about  $2\frac{1}{2}$  to 3 inches below the basket an anode is arranged in horizontal position, while with one hand a hand-anode is held over the small articles in the basket. By this arrangement a thicker deposit is more rapidly obtained, especially if with the other hand the articles are constantly stirred by means of a glass or wooden rod.

Warren has described a solution of nickel and one of cobalt which can be decomposed in a simple cell apparatus. With the nickel solution, which was prepared by dissolving 100 parts by weight of nickel chloride in as little water as possible and mixing with a concentrated solution of 500 parts of Rochelle salts, no satisfactory results could be obtained. The cobalt solution however yielded good results, and would seem to be suitable for electro-plating small objects *en masse*. It will be further referred to under "Cobalting."

In the last few years a number of contrivances for electro-plating small articles *en masse* have been patented, the articles to be plated being, as a rule, contained in a revolving perforated drum. The drums of some of the contrivances are constructed of non-conducting material so that the articles receive the current through copper or other metallic strips, which are secured in the inside walls of the drums, and are brought in various ways in contact with the source of current. In other contrivances, for instance, the apparatus of Smith & Deakin, metallic pins capable of being turned around the shaft, which is in contact with the negative pole of the source of current, reach to the layer of articles in the drum, and effect the re-conduction of the current. Since in the contrivances mentioned the anodes are placed outside of the drum, and the latter acts as a diaphragm with great resistance, a very high tension is required for the production of the deposit, independent of the fact that the articles being in constant motion require an essentially higher tension.

In another class of apparatus the six or eight-cornered drum is constructed of the same metal which is to be deposited. Every metal plate forming one side is insulated from the next plate. A commutator of special construction renders it possible for the plates which, while the drum is revolving, occupy the lowest position and upon which the articles for the time being rest, to be brought into contact with the negative pole of the source of current, while the positive current is carried to the plates occupying a higher position, they, therefore, acting as anodes. In these apparatuses the high resistance due to the arrangement of the anodes on the outside is overcome, but the commutator with the sliding contact constitutes a very sensitive part of this form of construction.

In the apparatus patented by Dr. George Langbein & Co. great resistance is avoided, while the construction is very simple.

A perforated drum of non-conducting metal is secured to a metal-shaft of the same material which is to be deposited. The drum together with the shaft revolves in metallic bearings to which the positive current is conducted. Contact pins are screwed in the shaft and above them is placed an anode rolled into the form of a cylinder, which is secured by screwing back the contact pins, so that it constantly revolves with the shaft and the drum containing the articles to be plated. Two or three copper strips are inserted inside the drum and secured by screws. They are connected by means of a sliding contact upon the face of the drum with the negative pole and, hence, bring the articles in contact with the current.

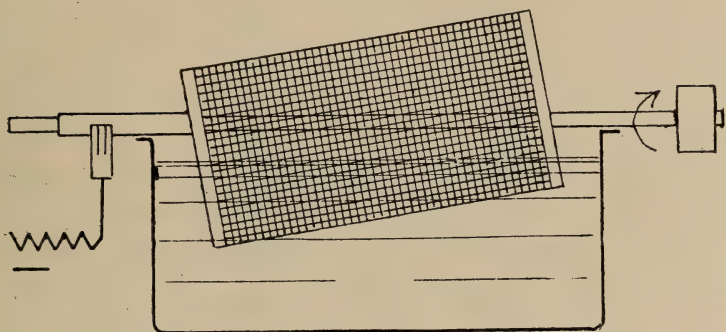
Pianhauser recommends the plating drum shown in Fig. 114 for plating small articles *en masse*.

Upon an iron shaft  $\frac{3}{8}$  to  $\frac{3}{4}$  inch in diameter are secured at a suitable distance two square discs of wood rich in rosin but free from tannin.

Around their circumferences is placed a tissue of thin brass or copper wire, with meshes as wide as possible, corresponding to the size of the articles, so that not a piece can fall through. An opening, best on one of the sides, is provided for the introduction of the articles.

Upon one end of the shaft is keyed a pulley or crank for slowly revolving the drum (about 20 revolutions per minute) by means of the transmission or by hand. Upon the other end of the shaft is secured a sliding contact—a strip of sheet metal—similar to the brushes of a dynamo, which is connected with the object-pole of the source of current. To bring the wire tissue in contact with the current-conducting shaft several thick, flat wires are soldered to the shaft, and being carried longitudinally outside over the drum, are soldered on the opposite face of the latter to the shaft. These wires have the further object of supporting the slight wire tissue. The whole is finally laid in two wooden bearings secured to the vat so that

FIG. 114.



the drum dips nearly up to the shaft into the bath. The anodes on both sides should be as large as possible and arranged at a distance of about  $5\frac{3}{4}$  inches from the sides of the drum.

The drum is moderately filled with articles and revolved. By the articles tumbling about the contact is constantly changed and they are plated on every side. By the constant friction of the articles against the wire tissue of the drum, the latter remains bright and sufficient contact is secured. If, however, this friction should not suffice to keep the tissue bright, other means must be adopted.

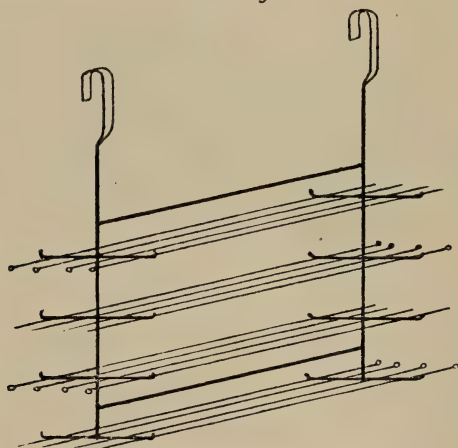
The contrivances described above, while suitable for electro-



plating small articles which it would be too expensive and time-consuming to string upon wires, are not adapted for plating such articles as rods, bicycle spokes, chains, etc., because by the revolution of the drum they would become so inextricably tangled and bent that uniform plating would be impossible, independent of the fact that by arranging the anodes in the interior of the drum a short circuit is immediately formed.

For plating such articles Dr. George Langbein & Co. have patented a rocking apparatus which does not exhibit the above-mentioned evils. It consists of a semicircular drum of non-conducting material, which contains the articles and is in contact

FIG. 115.



with the negative pole. The drum makes rocking movements around a stationary anode whereby the articles, for instance, spokes, are rolled from one side to the other and then back again. By this arrangement the spokes are not jumbled together as is always the case in closed revolving drums, a uniform deposit upon all portions of the articles is effected, and the latter come with a beautiful lustre from the apparatus.

For suspending bicycle spokes in the bath, Pfanhauser recommends the arrangement shown in Fig. 115. A deter-

mined number of spokes are at one time suspended in the bath, and by occasionally shaking them their position is altered in order to change the contact and produce uniform nickeling.

*Stripping nickeled articles.*—Defective nickeling must, as a rule, be completely removed before the objects can be re-nickeled, since the second deposit adheres badly to the previous one, especially if the latter has become dry. The removal of a nickel-deposit is in most cases a disagreeable labor, which, however, can most assuredly be saved if the utmost care and painstaking cleanliness are observed in freeing the articles from grease, and in regulating the current. For the removal of the nickel coating the following stripping acid, which may be used either cold or tepid, has been recommended: Sulphuric acid of 66° Bé., 4 lbs.; nitric acid of 40 Bé., 1 lb.; water about 1 pint. First put the water in a stoneware jar and cautiously add, a little at a time, the sulphuric acid, since considerable heat is generated when this acid is mixed with water. When the entire quantity of sulphuric acid has been added, pour in the nitric acid, when the bath is ready for use. In making up the stripping bath, the proportions of the acids may be varied, but the foregoing will be found to answer every purpose. An addition of 8 ozs. of potassium nitrate to the bath has also been recommended.

When stripping nickel-plated articles in the above bath it is necessary to watch the operation attentively, since some articles are very lightly coated and a momentary dip is frequently sufficient to deprive them of their nickel. Other articles which have been thoroughly well nickeled, but require from some accidental cause to be stripped and re-nickeled, will need immersion for several minutes—indeed well-nickeled articles may occupy nearly half an hour in stripping before the underlying surface is entirely bare. The operation of stripping should be conducted in the open air, or in a fire-place, so that the acid fumes, which are very pernicious, can escape freely. The articles should be attached to a stout copper wire, and after a few moments' immersion should be removed from the bath to

ascertain how stripping progresses. The moment it is found that the nickel has quite disappeared from every part, the article must be plunged into clean cold water. It is absolutely necessary that the work should not remain in the stripping solution one instant after the nickel is removed. When stripping has been properly effected, the underlying metal exhibits a bright, smooth surface, giving little evidence of the mixture having acted upon it.

Many platers, however, prefer to remove the nickel-coating mechanically by brushing with emery. From depressions it is as much as possible removed with the brush, after which the object is freed from grease and pickled, and coppered before nickeling. In this case the layer of copper serves for cementing together the old and new deposits, and there will be no danger of the new deposit peeling off in polishing.

It has also been proposed to remove the nickel from the articles by means of the battery or dynamo-machine by making them the anodes in a nickel-bath; but in this case a separate solution should be employed for the purpose.

As a remedy against the yellowish tone of the nickeling, Pfanhauser recommends suspending the nickeled articles, immediately after taking them from the nickel bath, as anodes in a nickel bath acidulated with citric or hydrochloric acid, a piece of sheet nickel serving as the cathode, and to allow the current to act for a few seconds. It is claimed that thereby the basic nickel salts separated together with the nickel, and to which, according to Pfanhauser, the yellowish tinge is due, are dissolved and the nickeling will show a pure white tone.

The following is a brief resume of the principal phenomena which may occur in nickeling, as well as the means of avoiding them:

1. The articles do not become coated with nickel, but acquire discolored, generally darker, tones. *Reasons:* The current is either too feeble to effect the reduction of nickel, and the coloration is due to the chemical action of the nickel solution upon the metals constituting the objects. This phenomenon

is frequently observed in nickeling zinc articles. *Remedy*: Increase the current or diminish the area of suspended objects; also examine whether the current actually passes into the bath, otherwise clean the places of contact.

2. A deposition of nickel takes place, but it is dark or spotted or marbled, even with a sufficiently strong current. *Reasons*: The bath is either alkaline, which has to be ascertained by testing with litmus-paper, and, if so, the slightly acid reaction of the bath has to be restored by the addition of a suitable acid; *or*, the bath is too concentrated, in which case a separation of crystals will be observed—this is remedied by diluting with water; *or*, the nickel solution is very poor in metal, which can be remedied by the addition of nickel salt; it should also be tested as to the admixture of copper, the production of dark tones being frequently due to this—in this case the bath is allowed to work for some time, and if the content of copper is inconsiderable a white deposit will soon be obtained; *or*, the cleaning and pickling of the articles have not been thoroughly done, which is remedied by again cleaning them; *or*, the conducting power of the bath is insufficient, which is remedied by the addition of a suitable conducting salt.

When freshly prepared baths yield dark nickeling, it can generally be remedied by working the bath two or three hours.

3. A yellowish tinge of the nickeling. *Reasons*: See under 2; *or*, with cast-iron an insufficient metallic surface, which is remedied by repeating the scratch-brushing; *or*, unsuitable composition of the bath.

4. The objects rapidly acquire a white deposit of nickel, but the color soon changes to dull gray-black, especially on the lower edges and corners. *Reason*: Too strong a current. *Remedies*: Regulating the current, or suspending more objects, or uncoupling elements. Frequent turning of the articles.

5. The nickeling is white, but readily peels off by scratching with the finger-nail or by the action of the polishing wheel. *Reasons*: The current is too strong, which is remedied as under 4; *or*, the bath is too acid—this is remedied by the addition of



spirit of sal ammoniac, potassium carbonate, or nickel carbonate, according to the composition of the bath; *or*, insufficient cleaning and pickling, which is remedied by thorough cleaning after removing the defective deposit, *or*, if it cannot be entirely removed, coppering.

6. Though nickeling may proceed in a regular manner, some places remain free from deposit. *Reasons*: Either the surfaces of some of the objects touch one another, or air bubbles are inclosed in cavities; *or*, faulty arrangement of the anodes. *Remedy*: Removal of the causes.

7. The deposit appears with small holes. *Reason*: A deposit of particles of dust upon the objects. *Remedy*: Remove the dust from the surface. When there is a general turbidity of the bath in consequence of alkalinity, add the most suitable acid, and boil and filter the bath; *or*, insufficient removal of gas bubbles from the objects. *Remedy*: Shake the object-rods by blows with the finger.

8. Deposition takes place promptly upon the portions of the objects next to the anodes, while deeper portions remain free from nickel or become black; *or*, the portions covered by the suspending wire show dark lines. *Reason*: Insufficient conducting power of the bath. With large depressions this cannot be remedied by the addition of a suitable conducting salt, but requires treatment with the hand-anode.

*Refreshing nickel baths*.—According to their composition, the amount of work performed, and the anodes used, the baths will in a shorter or longer time require certain additions in order to keep their action constant. By “refreshing” is not understood the small addition of acid or alkali from time to time required for restoring the original reaction of the baths, but additions intended to increase the metallic content and diminished conductivity.

The metallic content is increased by boiling the bath with some of the nickel salt used in its preparation, while the conductivity is improved by adding, at the same time, so much conducting salt as is necessary to restore the electro-motive

force originally required. Nothing definite can, of course, be said in regard to the quantity of such additions, it being advisable to observe their effect on a small portion of the bath, so as to be sure not to spoil the entire bath.

Nickel baths bear, as a rule, refreshing several times, but as in the course of time they take up impurities, even when the greatest care is exercised, it is best to refresh them at the utmost twice, and then to renew them entirely.

The *treatment of the articles after nickeling*, as well as after all electro-plating processes, has already been described, and it is only necessary here to refer again to the fact, that with articles of iron and steel, immersion in boiling water before drying in saw-dust is absolutely necessary, and subsequent drying in a drying chamber is also a great safeguard as regards stability and protection against rust.

*Nickel deposits are polished* upon felt wheels or bobs of cloth, muslin, or flannel, with the use of Vienna lime, rouge, etc. (See "Polishing," page 148.) Sharp edges, corners, and raised portions should be held only with slight pressure against the polishing wheels, they being more strongly attacked by them than flat surfaces. Knife-blades and surgical instruments with sharp edges require special care in polishing, which will be referred to later on.

After polishing, the nickeled objects, especially those with depressions, have to be freed from polishing dirt by brushing with hot soap-water or dilute hot caustic lye or benzine, then rinsed in hot water and dried in clean, fine saw-dust.

Objects which are not required to be polished, but left matt, that is, just as they come out of the nickel bath, should be taken from the bath one at a time, and at once plunged into perfectly clean hot water for a few moments, and then placed aside to dry spontaneously. Matt nickel being very readily stained or soiled, even when touched with clean hands, the work should be handled as little as possible.

*Nickeling sheet zinc.*—The nickeling of sheet zinc has been surrounded with a great deal of mystery by those engaged in

its manufacture, which may, perhaps, be excusable on the ground that there is scarcely another branch of the electro-plating industry in which experience had to be acquired at the sacrifice of so much money and time as in this. Nevertheless, the nickeling of sheet zinc makes no greater demand on the intelligence of the operator than any other electro-plating process, it requiring only an accurate consideration of the relations of the electric behavior of zinc towards nickel; consequently, a knowledge of the strength of the counter-current and of the chemical behavior of zinc towards the nickel solution, which may readily dissolve the zinc; further, a correct estimation of the current-intensity required for a determined zinc surface, as well as of the proper anode-surface, and the most suitable composition and treatment of the nickel baths.

With due observation of these relations, the nickeling of sheet zinc is accomplished as readily as that of other metals; and the suggestions to first cover the sheets in a bath with a strong current, and finish nickeling with a weaker current, or to amalgamate the zinc before nickeling, need not be considered.

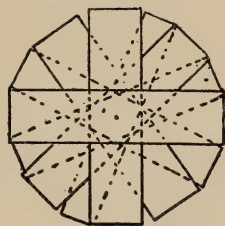
Below the conditions required for nickeling sheet zinc, and the execution of the process itself, together with the preliminary and final polishing of the sheets, will be found fully described.

The preliminary grinding or polishing is effected upon broad cloth wheels (buffs) formed of separate pieces of cloth. The polishing lathes run with their points in movable bearings secured in a hanging cast-iron frame by a set screw and safety keys, or preferably as shown in Fig. 98, since with this construction an injury to the grinder by the lathe jumping out is impossible.

The bobs, when new, have on an average a diameter of 12 to 16 inches, and a width of  $5\frac{3}{4}$  to 8 inches. The principal point in the construction of these bobs is uniform weight on all sides, quiet running and the possibility of a good polish without great exertion depending on this. Bobs not well balanced run unsteadily and jump, thereby producing fine scratches upon the sheet. The bobs are constructed as follows: A square piece

of cloth is folded fourfold and the closed point cut off with a pair of scissors, so that on unfolding the cloth the hole produced by the cut is exactly in the centre of the cloth disk. According to the diameter of the spindle more or less is cut away, but in every case just sufficient for the piece of cloth to be conveniently pushed upon the spindle. The latter, which is provided with a pulley and a hoop against which the pieces of cloth fix themselves, as well as with a nut and screw for securing them, is vertically fastened in a vise, and the separate pieces of cloth are pushed upon it so that the second piece placed in position forms an angle of about  $30^{\circ}$  (Fig. 116) with the first, the operation being thus continued until the bob has the desired width. Next a small, but very strong iron disk is laid upon the cloth bob, and the separate pieces are pressed together as firmly as possible with the screw. The spindle is then placed in the bearings, and after adjusting the belt upon the pulley the bob is revolved, a sharp knife being held against it to remove the projecting corners. In polishing sheet zinc the bobs make 2400 to 3000 revolutions per minute, according to whether finely rolled or rougher sheets are to be polished.

FIG. 116.

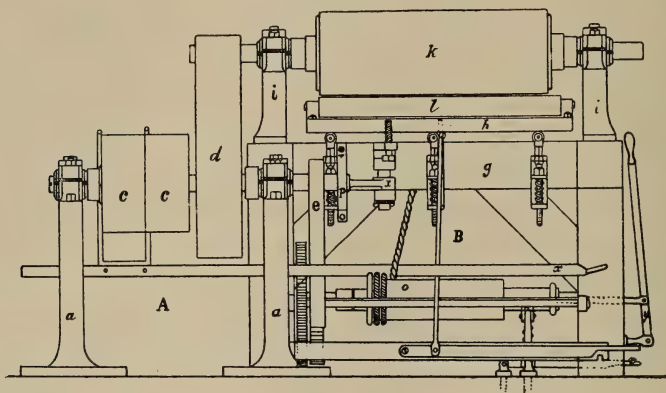


For the purpose of polishing or grinding, the operator places the sheet upon a support of hard wood of the same size and form as the sheet, and grasps the two corners of the sheet nearest to his body, together with the support, with the hands, applying with the balls of the hands the necessary pressure to hold the sheet upon the support. The lower half of the sheet, that furthest from the body, rests upon the knees of the operator, and with them he presses the sheet against the polishing wheel, constantly moving at the same time, and at not too slow a rate, the knees from the right to the left, then from the left to the right, and so on. Previous to polishing, a streak of oil about 2 inches wide is applied by means of a brush to the centre of the sheet in the visual line of the operator, and the



revolving bob is impregnated with Vienna lime by holding a large piece of it against it, when polishing of the lower portion of the sheet begins. When about  $\frac{3}{5}$  of the surface has thus been polished, the sheet is turned round and the remaining portion subjected to the same process. The sheet is then closely inspected to see whether there are still dirty or dull places, and, if such be the case, it is polished once more after moistening it with some oil and again impregnating the bob with Vienna lime. The sheet being sufficiently polished, the oil and polishing dirt are removed by dry polishing, after providing the bob with sufficient Vienna lime, so that the sheets when finished show no streaks of dirt or oil.

FIG. 117.



*Self-acting sheet polishing machines* have been constructed by Dr. Sackur, F. Räuber, Eliachoff, and others. Such machines give a very good polish, but have the disadvantage that thin sheets when polished upon some of them become wrinkled or wind up on the polishing roller.

In order to explain the principle upon which these machines are constructed, a description of F. Räuber's sheet grinding and polishing machine is given. With this machine metallic sheets of any length can be polished. By the simultaneous lateral and longitudinal motion of the sheets a faultless polish is obtained, streaks and scratches being especially avoided.

The machine essentially consists of the gearing *A* and the actual polishing machine *B*, Figs. 117, 118, 119. The gearing

FIG. 118.

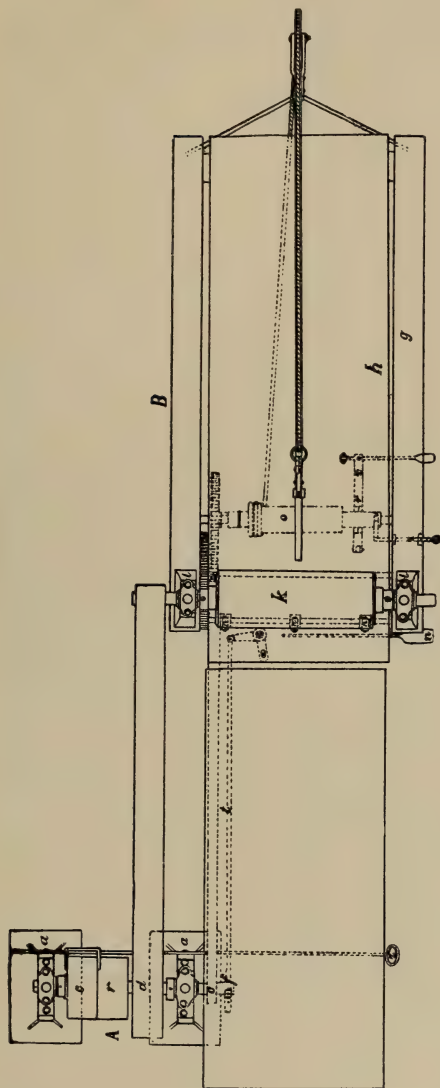
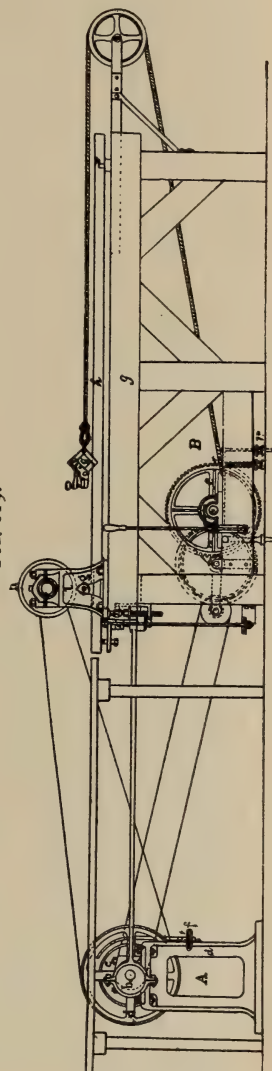


FIG. 119.



*A* consists of the two standards *a a*, the shaft *b*, a fast and loose

pulley, *c c*, the large driving-wheel *d*, a small driving-wheel, *e*, and the eccentric *f*.

The polishing machine *B* consists of the wooden frame *g* with wooden plate *h*, the two standards *i i*, the polishing roller *k*, the iron counter-roller *l*, the expanding contrivance *m*, which is effected by means of three spiral springs, the gearing *n* with the rope-drum *o*, the rope with the tongs *g*, and the shaking arrangement *x*.

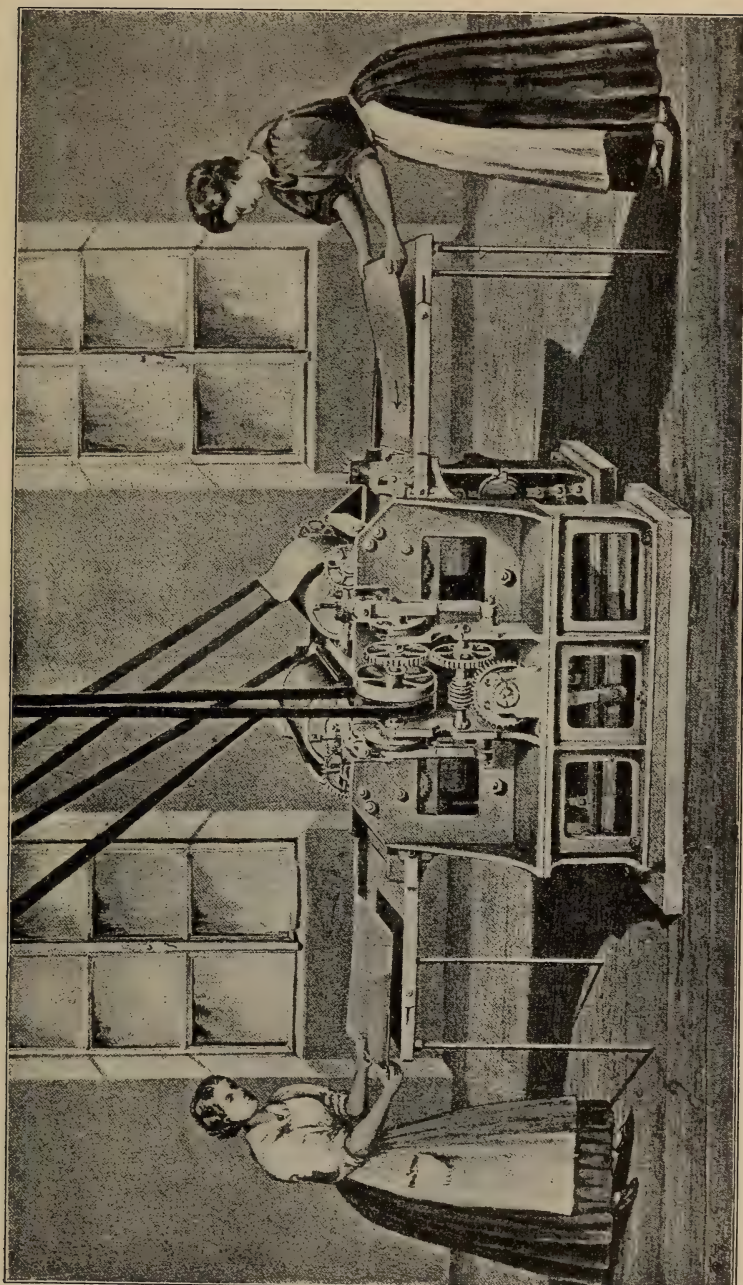
The machine is set in motion by the engaging coupling *x* on the gearing *A*. The shaft of the gearing makes about 200 revolutions per minute, and the polishing roller *k* is revolved by a belt from the driving-wheel *d*. At the same time the gearing *n* is set in motion by a belt from the driving-wheel *e*, in consequence of which the rope is wound upon the drum *o*, and the tongs on the rope draw the sheet to be polished under the polishing roller. If the sheet is to go back, the rope-drum *o* is disengaged by means of the coupling *y*, and the polishing roller *k*, which moves lightly upon the counter-roller *l*, draws the sheet back. To prevent the sheet from jumping back, the brake *r* is provided on the rope-drum *o*. By the treadle *r*, the workman is enabled to transport the sheet slowly or rapidly, as may be required. To move the sheet forward, the rope-drum *o* is again engaged. The lateral motion of the sheet is effected by the shaking contrivance *x*.

From the eccentric *f*, of the gearing *A*, the slide rod *t* is connected with the joint lever *x* and the latter by the pin *s* with the table plate *h*, whereby the latter when the machine is running is moved to the sides.

The centre of motion of the table plate is upon the pin *v*. To regulate the pressure of the sheet against the polishing roller, the expanding arrangement *m* is placed under the table plate *h*. It consists of three vertical bolts with spiral springs, each of which can be screwed up and down by a nut.

To facilitate the lateral motion of the table plate *h*, the bolts of the expanding contrivance *m* are provided with rolls which press against the plate. If the tension is sufficient and a sheet

FIG. 120.



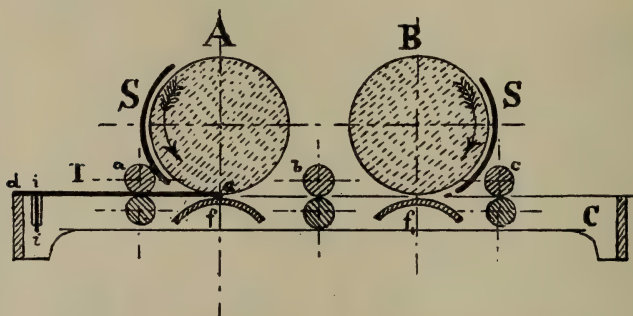


is to be introduced, it is only necessary to draw the table plate down by means of the treadle *w*, to push the sheet under the polishing roll *k*, and to engage the tongs *g*. In front of the gearing *A* is a table for the reception of the sheet, as shown in the illustration.

Fig. 120 shows an automatic sheet polishing machine constructed by F. W. Koffler of Vienna. It has the advantage of the sheets passing entirely free through the machine, their surfaces acquiring a fine polish free from scratches.

The machine works with two polishing rolls or buffs, *A* and *B*, Fig. 121, which revolve in the direction of the arrows. *C* is the polishing table upon which are mounted the two seg-

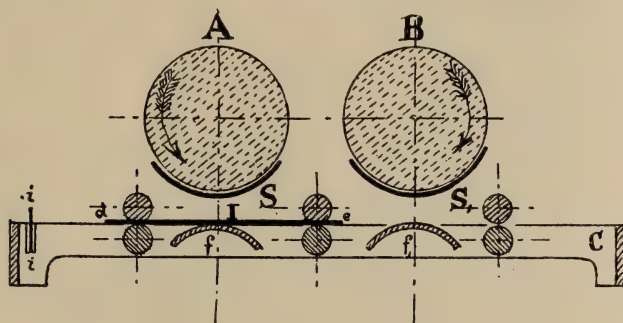
FIG. 121.



ments *ff*, for supporting the sheet, the two sliders *SS*, and the pairs of transporting rolls *a b c*. The sheet to be polished is at the entering place in front of the polishing roll *A* so delivered to the machine that the transporting rolls *a* catch the sheet and push it under the polishing roll *A*, when it is polished by the latter. For the solid support of the sheet while being polished, the segments *f* and *f*, are provided, the sheet sliding over them in passing through the machine. When the end *d* of the sheet *I* has reached the transporting roll *a*, the polishing table is, by the gearing of the machine, raised from the polishing rolls *A* and *B*, as shown in Fig. 122, and the sliders *SS*, assume a horizontal position. By this position of the sliders

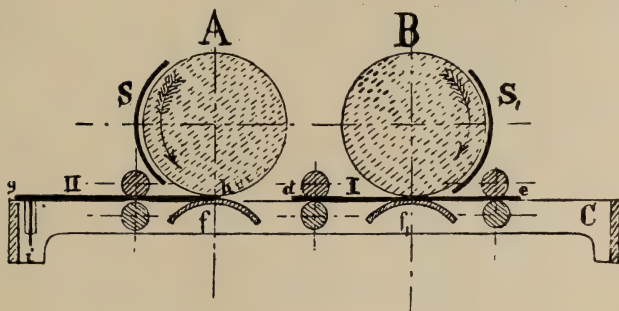
$SS_1$ , the sheet is prevented from rising and clinging to the polishing roll and the end  $d$  of the sheet is protected from being caught by the polishing roll. Since the transporting

FIG. 122.



rolls are in constant motion, the point  $e$  (the beginning of the sheet) will soon reach the transporting rolls  $c$ , Fig. 123, while the second succeeding sheet II, after the entering place has been released by the bolt  $i$ , is delivered to the machine,

FIG. 123.



reaches the vertex of the polishing roll  $A$ , and reversion by means of the mechanism of the machine having been accomplished, the polishing table assumes its former position and the sheets are pressed with the required force on the polishing rolls.

The polishing roll  $A$  operates upon two-thirds of the length

of the sheet from one end, and the polishing roll *B* upon two-thirds from the other end, so that the centre portion of the sheet is twice manipulated. Since the gearing of the machine requires uniform charging of the sheet, an automatic contrivance is provided whereby the entering place is at the proper time blocked by the bolt *i*, and again opened in order to deliver another sheet to the machine. The operation described is then repeated and from 600 to 800 sheets can in ten hours pass through the machine.

The automatic gearing can be arranged for lengths of 50, 100, and 150 centimeters (19.68, 39.37, and 59.05 inches), and sheets of different lengths may at the same time be polished.

The rapidity with which the sheets are passed through the machine is regulated by interchangeable wheels, according to the quality and effect desired.

The thinnest sheets (0.1 millimetre) can be polished upon this machine without danger of them puckering or clinging to the polishing roll. The machine is entirely constructed of iron. It is 8 feet 3.42 inches long, and 5 feet wide, and requires a power of 6 to 8 horse power, according to the condition of the sheets to be polished.

Fig. 124 shows an automatic sheet-polishing machine as constructed by Friedr. Krupp Grusonwerk, Magdeburg-Buckau, Germany.

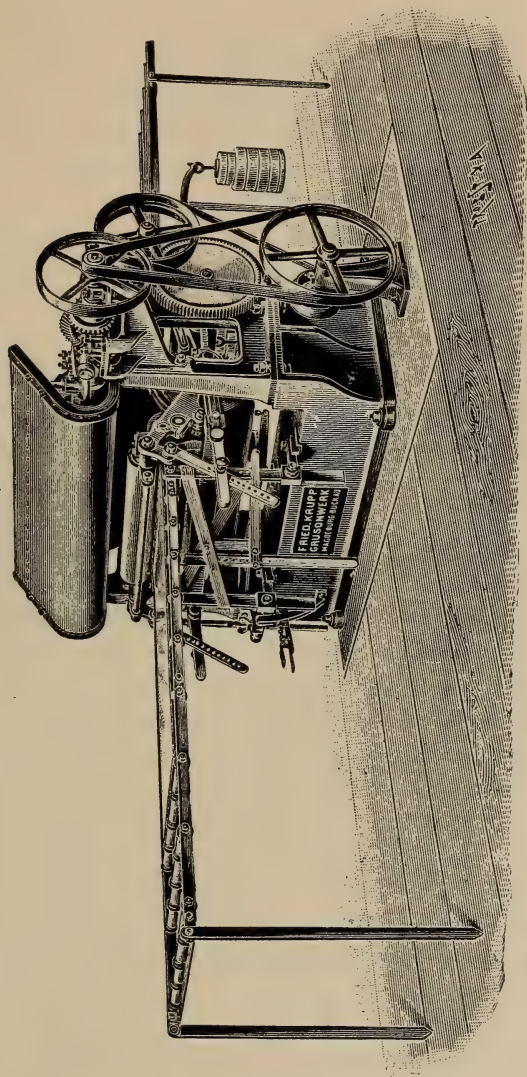
This machine serves for grinding and polishing sheets of brass, copper, nickel, zinc, nickel-zinc, and other metals of any thickness and in lengths up to 31.49 inches.

It consists essentially of a polishing roll having a revolving, and at the same time a sliding, motion. This polishing roll consists of cloth, felt, leather, wood, etc., according to the nature, condition, and the desired exterior of the sheets to be ground or polished. The sheets are pushed forward by a large hollow roll placed vertically under the polishing table, this roll together with smaller transporting rolls connected with it by spur wheels, serving at the same time for supporting the sheets.

The rapidity of the passage of the sheets through the ma-

chine is regulated, according to the thickness of the sheets and

FIG. 124.



the degree of polish desired, by driving wheels which can be readily interchanged and by step-pulleys of a connecting gear,



and with uninterrupted work amounts to about 295 feet per hour.

In order to exert with the large hollow pushing-roll a pressure corresponding to the degree of polish against the sheet lying upon it and against the polishing roll, its bearing is provided with a lever of the first kind by which the pressure—also while the machine is running—is regulated by means of a screw.

As soon as the machine is at rest, the pressure upon the polished sheet can be immediately released by a slight pressure of the foot upon the foot-lever, and the sheet taken from the machine, and another sheet introduced.

*Cleaning zinc sheets.*—The sheets are best freed from grease in two operations, first dry and then wet. For the dry process use a very soft piece of cloth and, after dipping it in Vienna lime very finely pulverized and passed through a hair sieve, rub over the sheet in the direction of a right angle to the polishing streaks, applying a very gentle pressure. For the wet process, dip a moist piece of cloth or a soft sponge free from sand into a paste of impalpable Vienna lime, whiting and water, and go carefully over the sheet so that no place remains untouched. Then rinse the sheet under a powerful jet of water, best under a rose, being particularly careful to remove all the lime, going over the sheet, if necessary, with a soft, wet rag, and observing whether all parts appear evenly moistened. If such be the case, cleaning is complete, otherwise the sheet has to be once more treated with lime.

If the sheets are to be nicked on only one side, two of them are placed together with their unpolished sides and fastened on the two upper corners with binding screws to which is soldered a copper strip about 0.39 inch wide, by which they are suspended to the conducting rods. Plating is then at once proceeded with, without allowing the sheets to remain exposed to the air longer than is absolutely necessary. Special care must be had that the lime does not dry, as this would produce stains

Some manufacturers nickel the cleansed sheets without pre-

vious coppering or brassing, and claim special advantages for such direct nickeling. This may be done with a bath of nickel sulphate and potassium citrate without, or with a greater or smaller addition of, sal ammoniac, according to the area to be nickeled and the intensity of current at disposal. However, sheet zinc directly nickeled does not show the warm full tone of sheets previously coppered or brassed; besides, direct nickeling requires a far more powerful current, so that it is not even more economical.

For the nickeling process itself, it is indifferent whether the sheets are previously coppered or brassed, but the choice between the two is controlled by a few phenomena which must be mentioned. The nickel deposit upon brassed sheets shows a decidedly whiter tone than that upon coppered sheets, and brassing would deserve the preference if this process did not require extraordinarily great care in the proper treatment of the bath, the nickel deposit readily peeling off, generally in the bath itself, which seldom or never occurs with coppered sheet, and then may generally be considered due to insufficient cleaning or other defective manipulation.

This peeling off of the nickel deposit may be prevented by giving due consideration to the conditions, and avoiding, on the one hand, too large an excess of potassium cyanide in the brass bath, and, on the other, by regulating the current so that no pale yellow or greenish brass is precipitated. Since nickeling with a strong current requires only a few minutes for a deposit of sufficient thickness capable of bearing polishing, it is generally desired to brass the sheets at the same time, so that the operation may proceed rapidly and continuously. To do this, a very powerful current has to be conducted into the brass bath, the result being that a deposit with a larger content of zinc and a correspondingly lighter color is formed, but also with a coarser, less adherent structure, and this is the principal reason why the nickel deposit, together with the brass deposit, peels off. To avoid this, the brassing must be done with a current so regulated that the deposit precipitates uniformly, adheres

firmly, and is not porous, the correct progress of the operation being recognized by the color being more like tombac, and not pale yellow or greenish. Where brassing has to be done quickly the content of copper in the brass bath must be increased to such an extent that a powerful current produces a deposit of the above-mentioned color, and, hence, too large an excess of potassium cyanide must be strictly avoided.

It will be seen that brassing requires a certain attention which is not necessary in coppering, and therefore the latter is to be preferred.

For coppering one of the baths, III. or V., given under "Deposition of Copper" can be used, to which, for this special purpose, more potassium cyanide may be added. The sheets should remain in this bath no longer than required to uniformly coat them with a beautiful red layer of copper, and under no circumstances must they be allowed to remain until the coppering commences to become dull or even discolored. They should come from the bath with a full, or at least half, lustre. When taken from the copper bath the sheets are thoroughly rinsed in a large water reservoir, the contents of which must be frequently renewed, care being had to remove any copper solution adhering to the unpolished sides which are not to be nickeled, since that would soon spoil the nickel bath. The sheets are then immediately brought into the nickel bath, it being best to suspend two, three, or four of them at the same time, to prevent one from being more thickly nickeled than the other, and take them out the same way. In suspending the sheets in the bath, care should be had to bring them as soon as possible in contact with the conducting rod, a neglect of this rule being apt to produce blackish streaks and stains.

Every separate nickel bath in which sheets are to be nickeled must be fed with the full current of a dynamo-machine, one of 250 to 300 ampères with 4 volts' tension being generally used. According to the number of sheets, generally 6 to 8, each 20x20 inches, to be nickeled, the dimensions of the vats are as follows: 63 inches long,  $15\frac{3}{4}$  inches wide, and  $25\frac{1}{2}$  inches deep, *or*, 83

inches long,  $15\frac{3}{4}$  inches wide, and  $25\frac{1}{2}$  inches deep. One to two minutes suffice to give 6 sheets a sufficiently thick deposit of nickel with a dynamo-machine of the above-mentioned capacity, and 2 to 3 minutes for eight sheets; and it may be accepted as a rule that, with a bath of good conductivity, a density of current of from 1.4 to 1.5 ampères and 5 volts' tension is required per 15.5 square inches of zinc surface for the solid nickeling of the sheets. For nickeling zinc in baths conducting with difficulty, for instance, a simple solution of sulphate of nickel and ammonia without the addition of conducting salts, or in baths containing boric acid, 1.3 to 1.4 ampères and 6 to 7 volts, must be allowed per 15.5 square inches of zinc surface if the nickeling is to be effected in the above named space of time. A density of current of 1.4 to 1.5 ampères and 4 to  $4\frac{1}{2}$  volts, at which the sheets have to remain in the bath for 3 minutes, is the most suitable, the deposit thus obtained being in every respect faultless, provided the nickel bath is of proper composition.

For nickeling sheet zinc, rolled anodes are, as a rule, only used, except when working with baths containing boric acid. The anode surface must at least be equal to that of the zinc surface. The distance between the anodes and the sheets should be from 3 to  $3\frac{3}{4}$  inches, and when the current-strength is somewhat scant the distance may be reduced to  $2\frac{1}{2}$  inches. The nickel anodes have to be taken from the bath once daily and scoured bright with scratch-brushes and sand. For the rest, all the rules given for nickel anodes are valid.

Baths used for nickeling sheet zinc soon become alkaline in consequence of the powerful current used, which is shown by red litmus-paper turning blue. The alkalinity also manifests itself by the bath becoming turbid and the nickeling not turning out pure white. The slightly acid reaction required is restored by citric acid solution. The appearance of the dreaded *black streaks* and *stains* is due either to the current itself being too weak or, to its having been weakened by an extremely great resistance of the nickel bath; also to an insufficient metallic surface of the anodes, which may be either too small or



not sufficiently metallic on account of tarnishing; and finally to an excessive alkalinity of the bath or insufficient contact of the hooks with the connecting rods.

The metallic content of the bath must from time to time be augmented by the addition of nickel salt, and the bath filtered at certain intervals. When the conductivity abates, it has to be restored by the addition of conducting-salt.

When the sheets have been sufficiently nickeled, they are allowed to drain off, then plunged into hot water, and, after removing the binding-screws, dried by gentle rubbing with fine sawdust free from sand and passed through a fine sieve to separate pieces of wood. In all manipulations, the unnickeled sides are placed together, while a piece of paper of the size and form of the sheets is laid between the nickeled sides.

The nickeled sheets are finally polished, which is effected by placing them upon supports and pressing against the revolving bob as previously described, the sheets being, however, only moderately moistened with oil, and not too much Vienna lime applied to the bob. Polishing is done first in one direction and then in another, at a right angle to the first. After polishing, the sheets are finally cleansed with a piece of soft cloth and impalpable Vienna lime, when they should show a pure white lustrous nickeling, free from cracks and stains, and bear bending and rebending several times without the deposit of nickel breaking or peeling off.

*Nickeling tin plate.* For elegant and durable nickeling, tin-plate also requires previous coppering. The deposit is effected with a less powerful current than for sheet zinc. Scouring is done as described for sheet zinc, also polishing of the nickeled tin-plate.

*Nickeling copper and brass sheets.* The treatment of these sheets differs from that of sheet zinc in that the rough sheets are first brushed with emery and then polished with the bob. After treating the sheets with hot caustic lye or lime-paste, they are pickled by brushing them over with a solution of 1 part of potassium cyanide in 20 parts of water. They are then

thoroughly and rapidly rinsed and immediately brought into the bath. To avoid peeling off, the current must not be too strong.

*Nickeling sheet-iron and sheet-steel.*—Only the best quality of sheet should be used for this purpose. After rolling, the sheets are freed from scales by pickling, then passed through the fine rolls, and finally again pickled. If the nickeled sheets are not to exhibit a high degree of polish, it suffices to brush them before nickeling with a large, broad, fibre brush (p. 145) and emery No. 00. But for a high lustre, such as is generally demanded, the sheets have first to be ground. For fine grinding the pickled sheets, broad massive wheels of poplar wood are used, which are covered with leather and turned like the wheels described on p. 142. These wheels are 10 to 12 inches in diameter, and 2 to 4 or more inches long, according to the size of the sheets. For the first grinding, the wheels are coated with glue and rolled in emery No. 100 to 120, according to the condition of the sheets, while emery No. 00 is applied to the wheels used for the fine grinding. The grinding is succeeded by brushing, as described on p. 144.

After preparing a sufficiently smooth surface, the sheets are at once rubbed with a rag moistened with petroleum, or, if preferred, with a rag and pulverized Vienna lime. They are then scoured wet in the manner described for sheet-zinc, p. 232. The scouring material must be liberally applied, especially if the sheets are to be directly nickeled without previous coppering, as is advisable. After rinsing off the lime-paste, the sheets are brushed over with very dilute sulphuric acid (1 part acid to 25 water), rinsed off, then lightly brushed over once more with lime-paste, again carefully rinsed, and immediately brought into the nickel bath.

The current should be neither too strong nor too weak, but regulated so that the deposit of nickel is of sufficient thickness in 15 to 20 minutes without showing a tendency to peel off. It is not advisable to try to obtain a heavy deposit in a shorter time, because it would lack density, which is the principal requirement for nickeled sheet-iron.

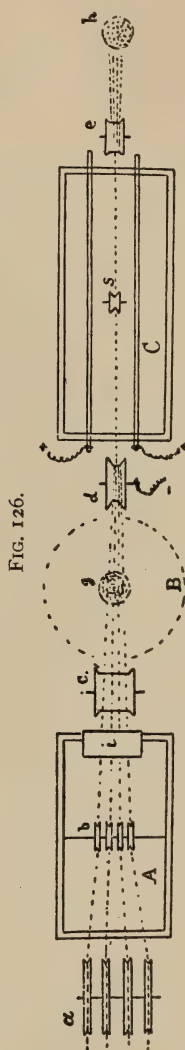
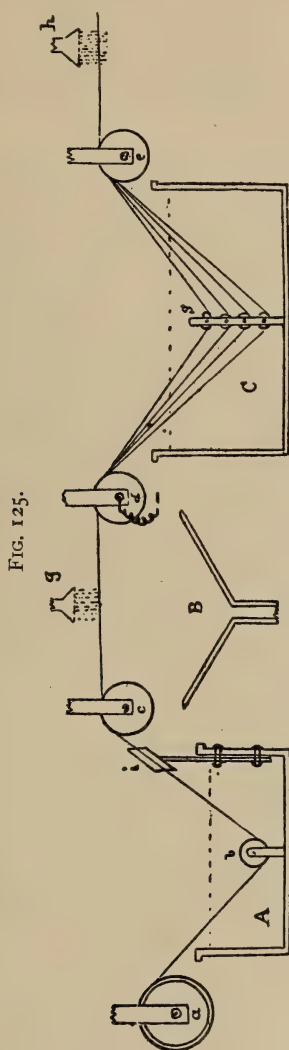
After nickeling, the sheets are rinsed in clean water, then plunged into hot water and dried by rubbing with warm sawdust. After this operation, it is recommended to thoroughly dry the sheets in an oven heated to between  $176^{\circ}$  and  $212^{\circ}$  F., to expel any moisture from the pores, and then to polish them with Vienna lime and oil, or with rouge.

*Nickeling wire.* Nickeling of wire of iron, brass, or copper is scarcely ever done on a large scale. It is, however, believed that the nickeling of iron and steel wires—for instance, piano-strings—might be of advantage to prevent rust or at least to retard the commencement of oxidation as long as possible.

To nickel single wires cut into determined lengths, according to the general rules already given, is simple enough; but this method cannot be pursued with wire several hundred yards long, rolled in coils, as it occurs in commerce. Nickeling the wire in coils, however, cannot be done, as only the upper windings exposed to the anodes would acquire a coat of nickel. Hence it becomes necessary to unwind the coil, and for continuous working pass the wire at a slow rate through the cleansing and pickling baths, as well as the nickel bath, and hot water reservoir, as shown in Fig. 125, in cross-section, and in Fig. 126, in ground plan.

The unwinding of the wire is effected by a slowly revolving shaft, upon which the nickeled wire again coils itself; but in the illustration the shaft is omitted. In Fig. 126 four wires run over the four rolls *a*, mounted upon a common shaft, to the rolls *b* upon the bottom of the vat *A*, whereby they come in contact with a thickly-fluid lime-paste in the vat, and are freed from grease. From the rolls *b* the wires run through the wooden cheeks *i*, lined with felt, which retain the excess of lime-paste, and allow it to fall back into the vat. The wires then pass over the roll *c* to the roll *d*. Between these two rolls is the rose *g*, which throws a powerful jet of water upon the wires, thereby freeing them from adhering lime-paste. The roll *d*, as well as its axis, is of brass, and to the latter is connected the negative pole of the battery or dynamo, so that by

carrying the wires over the roll *d* negative electricity is conducted to them. From the roll *d* the wires run over the roll-



bench *s* (Fig. 125) to the vat *C*, which contains the nickel solution, so that they are subjected to the action of the anodes



arranged in this vat on both sides of the wires. The wires then pass over the roll *e*, are rinsed under the rose *h*, and run finally through a hot water reservoir and sawdust (these two apparatuses are not shown in the illustration), to be again wound in coils. In case a high polish is required, the nickeled wires may be run under pressure through leather cheeks dusted with Vienna lime.

*Nickeling wire-gauze.*—Messrs. Louis Lang & Son obtained, in 1881, a patent for a method of nickeling wire-gauze, or wire to be woven into gauze, more especially for the purpose of paper manufacture. These wires, which are generally of copper or brass, are liable to be attacked by the small quantities of chlorine which generally remain in the paper pulp, by which the gauze wire eventually suffers injury. To nickel wire before it is woven, it is wound on a bobbin and immersed in a nickel bath in which it is coated with nickel in the usual way. It is then unwound and rewound on to another bobbin, and reimmersed in a nickel bath, as before, so as to coat such surfaces as were in contact with each other and with the first bobbin. To deposit nickel on the woven tissues it may either be coated in its entire length, as it leaves the loom, or in detached pieces. For this purpose the wire gauze is first immersed in a pickel bath, and next in the nickel solution. On leaving the latter it is rinsed and then placed in a hot air chamber, and when thoroughly dry may be rolled up again ready for use.

*Nickeling knife-blades, sharp surgical instruments, etc.* Considerable trouble is frequently experienced in nickeling sharp edged instruments, the edges and points being spoiled either by the deposit of nickel or in polishing. And yet such instruments can be readily nickeled in such a manner that the edges remain in as good condition as before.

If new instruments which have never been used are to be nickeled, no special preparation is required, it being only necessary to free them at once from grease and bring them into the bath. But instruments which have been used or, by bad treatment have become partly or entirely covered with rust,

must be first freed from rust by chemical or mechanical treatment, and then polished. The marks left by the stone or emery wheel are effaced by means of the circular brush, this treatment being necessary to obtain perfect nickeling. But in brushing the edges are rendered dull if special precautionary measures are not used. For instance, the edge of a knife-blade must never come in contact with the brush. This is prevented by firmly pressing the blade flat upon a soft support of felt or cloth, so that the edge sinks somewhat into the support, without, however, cutting into it. The edge is then held downward, and thus together with the support brought against the revolving brush. In this manner the blades may be vigorously brushed without fear of spoiling the edges.

The treatment in giving them a high polish after nickeling is the same. Freeing from grease may be done in the usual manner with lime-paste; but must also be effected upon a soft support, the same as in polishing. After thorough rinsing in clean water the separate pieces, *without* being previously coppered, are brought directly into the nickel bath, the composition of which must, of course, be suitable for nickeling steel articles. The instruments are first coated with the use of a strong current, so that the deposition takes place slowly and with great uniformity.

In suspending the articles in the bath, care should be had that neither a point nor an edge is turned towards the anodes. It is best to use a bath with anodes on one side only, and to suspend the blades with their backs towards the anodes. If, for any reason, the instruments are to be suspended between two rows of anodes, the edges should be uppermost, as near as possible to the level of the bath; but they should never hang deep or downwards.

The plated instruments are given a fine lustre by polishing, but during this operation they must always be exposed upon a soft support, as above described, to the action of a felt wheel, or, still better, of a cloth bob.

In nickeling *skates* it is advisable to suspend them so that the

runners hang upwards and that the running surfaces are level with the surface of the bath, because if the deposit upon the running surfaces is too thick, it peels off readily when injured by grains of sand upon the ice.

*Nickeling printing plates (electrotypes, clichés, etc.)* The advantages of nickeling electrotypes, etc., over steeling will be referred to under "Steeling," and hence only the most suitable composition of the nickel baths and the manipulations required will here be given.

The nickel baths according to formula I. (page 190) and formula VII. (page 193) are the most suitable for simple nickeling, because the ammonium sulphate not being present in too great an excess, as well as the presence of boric acid, causes the nickel to separate with considerable hardness. With nickeled electro-plates three times as large an addition can be printed as with plates of the same material not nickeled.

It being a well-known fact that a fused alloy of nickel with cobalt possesses greater hardness than either of the metals by themselves, experiments proved that an electro-deposited nickel-cobalt alloy exhibited the same behavior, the greatest degree of hardness being attained with an addition of cobalt varying between 25 and 30 per cent. For this deposit the term *hard nickeling* is proposed, the most suitable baths for the purpose being prepared according to the following formulæ:

I. Nickel-ammonium sulphate 21.16 ounces, cobalt-ammonium sulphate 5.29 ounces, ammonium sulphate 8.8 ounces, water 10 to 12 quarts; *or*,

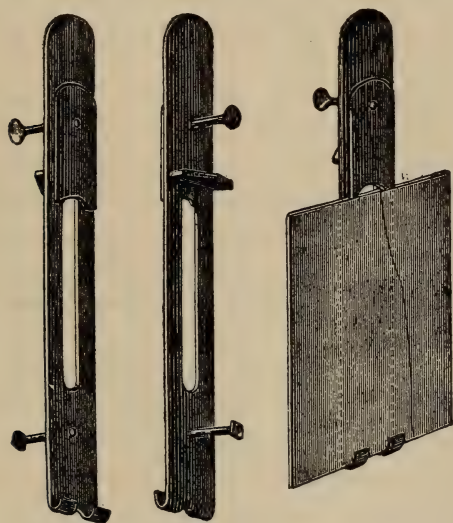
II. Nickel-ammonium sulphate 21.16 ounces, cobalt-ammonium sulphate 5.29 ounces, crystallized boric acid 10.58 ounces, water 10 to 12 quarts.

Bath No. I. is prepared by simply dissolving the salts in hot water, and, in case the bath is too acid, adding spirits of sal ammoniac until blue litmus paper is only slightly reddened. It is best to use rolled and cast anodes in equal proportions; and when the bath becomes alkaline to restore its original slightly acid reaction by the addition of citric acid.

To prepare bath No. II. dissolve the constituents by boiling; and in case not entirely neutral metallic salts have been used, add to the hot solution, with constant stirring, 1 to  $1\frac{3}{4}$  ounces of nickel carbonate for the neutralization of free sulphuric acid which may be present. This bath must not be neutralized, but worked with its strongly acid reaction, mixed anodes being also used.

The bath prepared according to formula No. II. deserves the preference, it yielding a harder deposit than bath No. I.

FIG. 127.



For the rest, the treatment of the baths is the same as that given for nickel baths of similar composition (pp. 190 and 193), and the process of hard nickeling does not essentially differ from ordinary nickeling. The suspending hooks are soldered to the backs of the plates by means of the soldering-iron and a drop of tin; or the plates are secured in holders of sheet-copper 0.11 inch thick, and  $\frac{3}{4}$  to 1 inch wide, of the form shown in Fig. 127. The printing surface is freed from grease by brushing with lime-paste, rinsing in water, and then brushing



with a clean brush to remove the lime from the depressions. The plates are then hung in the bath and covered with a strong current. When everywhere coated with nickel the current is weakened and the deposit allowed gradually to augment. With an average duration of nickeling of 15 to 20 minutes, with 2.8 to .3 volts, the deposit will, as a rule, be sufficiently resisting.

The nickeled plates are rinsed in water, then plunged in hot water, and dried in sawdust, when the nickeled printing surface may be brushed over with a brush and fine whiting, it being claimed that plates thus treated take printing-ink better, while the first impressions of plates not brushed with whiting are somewhat dull.

Nickel-facing is especially suitable for copper plates for color-printing, the nickel not being attacked like copper or iron by vermilion.

*Recovery of nickel from old baths.*—At the present price of nickel its recovery from old solutions scarcely pays. The uselessness of the bath is in most cases due to two causes: It has either become too poor in metal or it contains foreign metallic admixtures. In the first case, the expense of evaporating with the further manipulation is out of proportion to the value of the nickel recovered; and, in the second case, the reduction of the foreign metals is inconvenient and connected with expenses which make it unprofitable.

Urquhart proposes the following plan for recovering nickel from old solutions: Make a saturated solution of ammonium sulphate in warm water, and add to it the old nickel-plating solution with constant stirring, and, after the lapse of a few minutes, a granular precipitate of the double sulphate of nickel and ammonium will begin to separate. The addition of ammonium sulphate should be continued from time to time until the liquid is colorless. The precipitated salt is very pure, and may be used directly in making a new bath.

*To improve defective nickeling.*—With the basis-metal thoroughly cleansed defective places should not occur, but when

they happen, by accident or negligence, recourse is to be had to "doctoring." The "doctor" is arranged as follows: A piece of stout copper wire is bent in the form of a hook at each end, and a fragment of nickel anode is fastened firmly to one of the hooks with a piece of twine. The fragment of anode is then wrapped in several folds of muslin, the second hook connected by a wire to the anode-rod of the bath, and the article put in contact with the negative electrode. The rag end is now dipped in the nickel bath, applied to the defective spot, and allowed to rest upon it for a few moments, then dipped again and reapplied. By repeatedly dipping the rag in the nickel bath and applying it in this way, a sufficient coating of nickel may be given in a few minutes; and if the operation is skillfully performed, no trace of the patch will be observable after polishing.

*Nickeling by contact and boiling.*—Franz Stolba has described a nickeling process by contact, which is executed as follows:—

In a bright copper kettle heat to boiling a concentrated solution of zinc chloride with an equal or double the volume of soft water, and then add drop by drop pure hydrochloric acid until the precipitate formed by diluting the zinc chloride solution with water disappears. Then add as much zinc powder as will lie upon the point of a knife, the effect of this addition being that the copper of the kettle so far as it comes in contact with the solution is in a few minutes zincked. Now bring into the kettle sufficient nickel salt, best nickel sulphate, to color the fluid perceptibly green. Then introduce the articles to be nickeled together with small pieces of sheet zinc or zinc wire, so as to present many points of contact, and continue boiling. With a correct execution of the process it is claimed the articles will be uniformly nickeled in 15 minutes. If such is not the case, the boiling must be continued, fresh pieces of zinc added, or, if the solution does not appear sufficiently green, fresh nickel salt introduced.

For the success of the process several conditions are necessary. The metallic articles must be thoroughly freed from

grease, as otherwise no deposit of nickel is formed on the greasy places. In boiling, the solution must not become turbid by the separation of basic zinc salt, nor acid by free hydrochloric acid, otherwise the nickeling will be dull and blackish. Hence, any turbidity must be at once removed by adding drop by drop hydrochloric acid, and too great acidity by the careful addition of solution of carbonate of soda. The articles thus nickeled are to be thoroughly washed with water, dried, and polished with whiting.

Since stains are readily formed by this process, especially when nickeling polished iron and steel articles, on the places where the metal to be nickeled comes in contact with the zinc, Stolba in later experiments omitted the zinc, and thus the contact process becomes a boiling process. To a 10 per cent. solution of zinc chloride add enough nickel sulphate to give the solution a deep green color and then heat, best in a porcelain vessel, to the boiling-point. Then without troubling about the turbidity of the bath caused by the separation of a basic zinc salt, immerse the objects, previously cleansed and freed from grease, in it in such a way that they do not touch each other, or at least in only a few places, and keep the whole boiling 30 to 60 minutes, from time to time replacing the water lost by evaporation. The after-treatment is the same as given above for the contact process. The deposit of nickel is, of course, very thin.

This process, while suitable for the amateur, cannot be recommended to the professional electro-plater, the results not being sufficiently sure. A thin deposit of nickel of a light color may be obtained upon brass articles, but that upon iron articles is dark and mostly stained.

Small articles, which are not to be nickeled by the electric current, are preferably coated by contact with cobalt by the process to be described later on, under "Deposition of cobalt." The higher price of cobalt salts makes little difference, small quantities only being required, and the color of cobalt can scarcely be distinguished from that of nickel.

By boiling a solution of  $8\frac{1}{2}$  ozs. of nickel-ammonium sulphate and  $8\frac{1}{2}$  ozs. of ammonium chloride in 1 quart of water, together with clean iron filings free from grease, and introducing into the fluid copper or brass articles, the latter become coated with a thin layer of nickel capable of bearing light polishing. The nickel solution has to be frequently renewed.

According to experiments made by Dr. George Langbein, it is more advantageous to substitute a small piece of aluminium sheet for the iron filings and to touch with it the articles to be nickered in a hot bath (about  $185^{\circ}$  to  $194^{\circ}$  F.) Or, string small articles upon an aluminium wire, though if this cannot be had, zinc wire may be used.

According to R. Kaiser, an alloy containing nickel may be deposited upon articles by proceeding as follows: Melt 1 part of copper and 5 of tin, and granulate the fused mass by pouring it through a heated sheet-iron sieve into a bucket filled with water. Boil the granulated metal thus obtained with tartar free from lime, and add for every 100 parts by weight of granulated metal 0.5 part of nickel oxide previously ignited. Then bring the brass or copper articles, previously freed from grease and pickled, into the boiling fluid, and after boiling for a short time they will appear coated with a white alloy resembling German silver. The addition of nickel oxide must be repeated from time to time. Iron and steel articles are to be previously coppered. By adding nickel carbonate to this bath, it is claimed, coats richer in nickel and of a darker color than that of platinum to blue-black are obtained.

*Deposits of nickel alloys.*—From suitable solutions of the metallic salts nickel may be deposited together with copper and tin, as well as with copper and zinc. With the first combination, especially, all tones from copper-red to gold-shade may be obtained, according to which metal predominates, or according to the current-strength which is conducted into the bath, as is also the case in brassing.

A suitable bath for coating metallic articles with an alloy of nickel, copper, and tin, for which the term *nickel-bronze* is pro-



posed, is obtained by dissolving the metallic phosphates in sodium pyrophosphate solution. By mixing solution of blue vitriol with solution of sodium phosphate, cupric phosphate is precipitated which is filtered off and washed. In the same manner nickel phosphate is prepared from a solution of nickel-sulphate. These phosphates are then, each by itself, dissolved in a concentrated solution of sodium pyrophosphate, while chloride of tin is directly dissolved in sodium pyrophosphate until the turbidity, at first rapidly disappearing, disappears but slowly.

Nothing definite can be said in regard to the mixing proportions of these three solutions, because the proportions will have to be varied according to the desired color of the deposit. The operator, however, will soon find out of which solution more must be added in order to obtain the tone desired.

For depositing an alloy of nickel, copper, and zinc, solutions of cupric sulphate (blue vitriol) and zinc white in potassium cyanide, to which is added an ammoniacal solution of nickel carbonate, may be advantageously used.

According to a French process, a deposit of German silver may be obtained as follows: Dissolve a good quality of German silver in nitric acid and add, with constant stirring, solution of potassium cyanide until all the metal is precipitated as cyanide. The precipitate is then filtered off, washed, dissolved in potassium cyanide, and the solution diluted with double the volume of water. This process, however, does not seem very feasible, since nickel separates with difficulty from its cyanide combination.

Watt recommends the following method: Cut up into small pieces sheet German silver about 1 oz., place the strips in a glass flask, and add nitric acid diluted with an equal bulk of water. Assist the solution of the metal by gentle heat. When red fumes cease to appear in the bulb of the flask, decant the liquor and apply fresh acid, diluted as before, to the undissolved metal, taking care to avoid excess; it is best to leave a small quantity of undissolved metal in the flask, by which an excess

of acid is readily avoided. The several portions of the metallic solutions are to be mixed and diluted with about 3 pints of cold water in a gallon vessel. Next dissolve about 4 ozs. of carbonate of potash in a pint of water, and add this gradually to the former, with gentle stirring, until no further precipitation takes place. The precipitate must be washed several times with hot water, and then redissolved by adding a strong solution of cyanide, with stirring, and about 1 oz. of liquid ammonia. To avoid adding too great an excess of cyanide, it is a good plan, when the precipitate is nearly all dissolved, to let it rest for half an hour or so, then decant the clear liquor, and dissolve the remainder of the precipitate separately. A small excess of cyanide solution may be added as "free cyanide," and the whole mixed together and made up to one gallon with cold water. The solution should then be filtered or allowed to repose for about 12 hours, and the clear liquor then carefully decanted from any sediment which may be present from cyanide impurities. The bath must be worked with a German-silver anode, which should be of the same quality as that from which the solution is prepared; a Bunsen battery should be employed as the source of electricity, or a dynamo-machine.

#### EXAMINATION OF NICKEL-BATHS.

The reactions of the nickel baths have previously been briefly referred to, but the subject must here be more closely considered.

For the determination of the content of acid, a different method must be adopted according to the composition of the bath, *i. e.*, whether it has been prepared with an addition of citric acid, boric acid, etc. The reddening of blue litmus paper simply indicates the presence of free acid in the bath, but leaves us in the dark as to which acid is present, and as to its derivation.

If, for instance, in consequence of insufficient solution of nickel, free sulphuric acid appears on the anodes, the bath becomes at the same time poorer in nickel in proportion to the

increase in the content of free sulphuric acid. If we have to deal with a bath prepared from nickel ammonium sulphate with an addition of ammonium sulphate, but without organic acids, the reddening of blue litmus paper will at once indicate a content of free sulphuric acid, if the bath was neutral in the beginning. It is, however, quite a different matter when a bath containing boric acid is examined. In the formulæ for preparing these baths, it has been seen that before adding the boric acid, any free sulphuric acid of the nickel salt present is to be removed by treating the solution with nickel carbonate or nickel hydrate. After adding the boric acid, blue litmus paper is strongly reddened, and this acidity due to the boric acid is to be maintained in the bath. However, in consequence of the use of too large a number of cast anodes, free sulphuric acid may form in the bath and this, together with boric acid, cannot be recognized by blue litmus paper, since both acids redden it. In this case red congo paper, which is not changed by boric acid, but is turned blue by sulphuric acid, has to be used. If red congo paper is colored blue, it is a sure proof that, besides boric acid, free sulphuric acid is present, which has to be neutralized for the bath to work in a correct manner.

The process is again different when a bath prepared with an addition of citric acid is to be examined. This organic acid colors certain varieties of commercial congo paper blue, just like sulphuric acid does, and hence tropaeolin paper has to be used, which is not altered by citric acid, but is colored violet by free sulphuric acid.

If a nickel bath has been prepared with the addition of organic salts, for instance, sodium citrate, ammonium tartrate or others, the formation of free sulphuric acid in the bath cannot at first be determined with reagent papers, because the sulphuric acid decomposes the organic salts, neutral sulphates being formed, and a quantity of organic acid equivalent to the sulphuric acid is liberated. For this reason the content of metal in the bath declines, though the presence of sulphuric acid cannot be established, because the sulphuric acid formed

by electrolysis is not consumed for the solution of nickel on the anodes, but for the decomposition of the organic salts.

Now let us suppose the reverse, namely, that in a nickel bath prepared with the addition of one of the above mentioned acids, free ammonia appears in consequence of the sole use of cast anodes, and of the decomposition of ammonium sulphate by a strong current. This phenomenon cannot at once be recognized, because the ammonia is first fixed by the free acid and the bath becomes neutral or alkaline only when all the free acid which was present has been consumed for fixing the ammonia formed. With this process there will generally be connected an increase in the content of metal, and it will be seen, without further explanation, that for the accurate determination of the processes and alterations in a nickel bath when in operation, the quantitative determination of the free acids, and as much as possible, that of the content of metal is required.

Although it must be said that the busy electroplater will frequently not feel inclined to familiarize himself with the methods of testing, and seldom have the necessary time for executing the determinations of the content of metal, nevertheless the methods will here be described with sufficient detail so that those who wish to examine their baths in this respect will find the necessary instructions. To be sure, if the electroplater himself is not a practical analytical chemist he will have to be taught by some one thoroughly conversant with the subject, the management of the analytical balance, how to execute the weighings, etc. It is also advisable to procure the standard solutions required for volumetric analysis from a reliable chemical laboratory, in order to avoid the possibility of arriving at incorrect results by the use of inaccurately prepared standard solutions. For this reason directions for the preparation of standard solutions are omitted, and the methods of examination in use for our purposes will now be given.

The examinations may be made by gravimetric analysis (analysis by weight), volumetric analysis (analysis by measure), and by electrolytic analysis. The first method is based

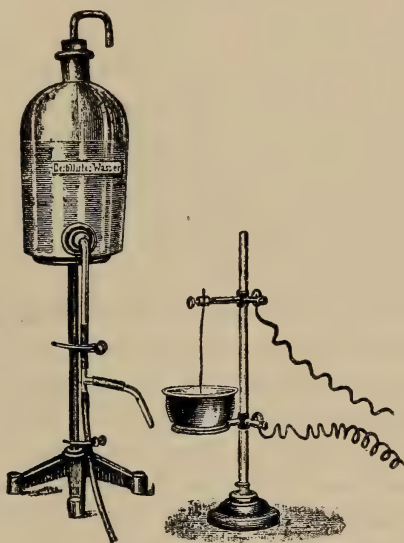


chiefly upon the precipitation in an insoluble form of the constituent to be determined, and filtering, washing, drying, and weighing the precipitate. This method requires considerable knowledge of chemistry and analytical skill, and should only be resorted to by those not versed in analysis, when other more practical methods for the determination of the contents, such as volumetric and electrolytic methods, are not known.

*Volumetric analysis* is based upon a very different principle from that of gravimetric analysis. The constituent to be ascertained is quantitatively determined by means of a standard solution, enough of which is used until the final reaction shows that a sufficient quantity has been added. From the known content of the standard solution, the constituent to be determined is then calculated. This may be explained by an example. For instance, the content of sulphuric acid in a fluid is to be determined. Measure the quantity of fluid by means of a pipette which up to a mark holds exactly 10 cubic centimeters. Allow the fluid to run into a clean beaker, dilute with about 30 cubic centimeters of water, and heat to about 122° F. Now, while constantly stirring the fluid in the beaker with a glass rod, add standard soda solution from a glass burette provided with a glass cork and divided into  $\frac{1}{10}$  cubic centimeters until a piece of congo paper when touched with the glass rod is no longer colored blue. The addition of the standard soda solution must of course be effected with great care. So long as the congo paper shows a vivid blue color, a larger quantity may at one time be added, but when the coloration becomes less vivid, the solution is added drop by drop so as to be sure that the last drop is just sufficient to prevent the blue coloration which was still perceptible after the addition of the previous drop. The drop-test must, of course, be made upon a dry portion of the congo paper, which has not been previously moistened. When no blue coloration appears after the last drop has been added, it is a proof that all the sulphuric acid present has been neutralized by the standard soda solution. The number and fractions of cubic centimeters consumed are

then read off on the burette, and the quantity of sulphuric acid present is calculated as follows: 1 cubic centimeter of standard soda solution neutralizes 0.049 gramme of sulphuric acid ( $\text{H}_2\text{SO}_4$ ) and hence the quantity of sulphuric acid is obtained by multiplying the number of cubic centimeters of standard soda solution by 0.049. Now, since 10 cubic centimeters were measured off by the pipette and titrated, the number found is multiplied by 100, which gives the content of sulphuric acid in 1 liter of the fluid.

FIG. 128.



If, for instance, for the neutralization of 10 cubic centimeters of the fluid containing sulphuric acid, 5.4 cubic centimeters of standard soda solution were required, then the content of sulphuric acid amounts to  $5.4 \times 0.049 = 0.2646$  gramme, or in 1 litre to  $0.2646 \times 100 = 26.46$  grammes.

*The electrolytic method of analysis* is available only for the determination of such metals as can be completely separated in a coherent form from their solutions by the current. It is based upon the fact that the metallic solution contained in a

platinum dish is decomposed by the current, and the metal precipitated upon the platinum dish. After washing and drying, the dish is weighed and the weight of the precipitated metal is obtained by deducting the weight of the platinum dish without precipitate, which, of course, has been ascertained before making the experiment.

The apparatus generally used for electrolytic analysis is shown in Fig. 128. The platinum dish, holding about  $\frac{1}{4}$  liter, rests upon a metal ring which is secured to the rod of the stand, and is in contact with the negative pole of the source of current. Into the dish, at a distance of 1 or 2 centimeters from the bottom, dips a round platinum disk bent like the bottom, or a spiral of platinum wire, 1 millimeter thick, which serves as anode and is secured by platinum wire in a movable support or holder. The latter is carefully insulated from the rod of the stand and connected with the positive pole of the source of current. During electrolysis the platinum dish is covered with a perforated watch-glass to prevent possible loss by the evolution of gas.

Since many precipitates have to be washed without interrupting the current, it is best to use the washing contrivance shown in the illustration to prevent the precipitated metal from being redissolved by the electrolyte. With the upper clip closed, the shorter leg of the siphon is dipped into the dish. The lower clip is then closed and the upper one opened until the short leg is filled with water. The upper clip is then closed and the lower one opened, whereby the dish is emptied. The clip of the longer leg of the siphon is then closed, the uppermost clip opened, and the dish filled up to the rim with water. The uppermost clip is then closed, the lower one opened, and the dish emptied the second time, the operation being repeated until the precipitate and dish are thoroughly washed.

Since for complete electrolytic precipitation it is essential to operate with correct current-tensions, it is advisable to use an accurate current-meter adjusted to 0.05 to 2.5 ampères, as well as a voltmeter.

The current for electrolysis may be supplied by elements, a thermo-electric pile, a dynamo, or an accumulator, but the necessary regulating resistances must in every case be provided.

Let us now return to the examination of nickel baths. If by qualitative analysis the presence of free sulphuric acid in the bath has been established, it can be at once assumed that the content of nickel has from the first declined. Hence it will scarcely be worth while to determine by volumetric analysis the quantity of free sulphuric acid present, and to calculate from this the quantity of nickel carbonate or nickel hydrate required for neutralization. It will be only necessary to add to the bath, stirring constantly, small portions of the nickel salt rubbed up with water, until a fresh test with congo paper shows no blue coloration. The addition of a small excess of nickel carbonate or nickel hydrate is unobjectionable. Besides neutralizing the free sulphuric acid, care should at the same time be taken to prevent its further formation by increasing the number of cast nickel anodes. The case is similar when a nickel bath prepared with organic salts, for instance, with potassium citrate or sodium citrate, is to be examined. Even if it is shown by the reaction that no free sulphuric acid is present, the content of nickel, as previously mentioned, may have decreased, and the content of free organic acid increased. The latter may, however, be neutralized by the addition of nickel carbonate or nickel hydrate and, hence, the determination of the content of acid by volumetric analysis is not absolutely necessary.

When, on the other hand, a nickel bath has become alkaline, the determination of the free alkali by volumetric analysis will be of little value, and it will, according to the composition of the bath, suffice to neutralize it with dilute sulphuric acid, or acidulate it with an organic acid. Since, however, baths which have become alkaline possess a higher content of nickel than the normal bath, an electrolytic determination of the nickel may be of use in order to calculate accurately the quantity of water which has to be added to reduce the content of nickel to the normal quantity.



If the bath has been prepared with nickel-ammonium sulphate with additions of ammonium sulphate, or boric acid, or if it contains only very small quantities of organic acids, it can be directly electrolyzed.

Bring by means of the pipette exactly 20 cubic centimeters of the bath into the platinum dish, add 4 grammes of ammonium sulphate and 35 to 40 cubic centimeters of ammonia of 0.96 specific gravity and electrolyze with a current-density = 0.6 ampère, until no dark coloration appears after adding a drop of ammonium sulphate to a few cubic centimeters of the electrolyte. Rinse the dish, together with the precipitate, with water, remove the water by rinsing with absolute alcohol, rinse the dish with pure ether and dry it at  $212^{\circ}$  F. in an air-bath. The weight of the precipitate of metallic nickel obtained by weighing the platinum dish gives the content of nickel ammonium sulphate in grammes per liter of bath by multiplying by 335. From the increase in the content of nickel ammonium sulphate shown by the analysis, it can be readily calculated, how much water has to be added to the bath to reduce it to the original content.

If a nickel bath contains large quantities of organic acids, precipitate 20 cubic centimeters of the bath with sodium sulphide solution, filter and wash the precipitate, dissolve it in nitric acid, and evaporate the solution with pure sulphuric acid upon the water-bath to drive off the nitric acid. The residue is treated as above described.

## 2. *Deposition of Cobalt.*

*Properties of cobalt.*—Cobalt has nearly the same color as nickel, with a slightly reddish tinge; its specific gravity is 8.56. It is exceedingly hard, highly malleable and ductile, and capable of taking a polish. It is slightly magnetic, and preserves this property even when alloyed with mercury. It is rapidly dissolved by nitric acid, and slowly by dilute sulphuric and hydrochloric acids.

For plating with cobalt, the baths given under nickeling may

be used by substituting for the nickel salt a corresponding quantity of cobalt salt. By observing the rules given for nickel-  
ing, the operation proceeds with ease. Anodes of metallic cobalt are to be used in place of nickel anodes.

Nickel being cheaper and its color somewhat whiter, electro-  
plating with cobalt is but little practiced. On account of the  
greater solubility of cobalt in dilute sulphuric acid it is, how-  
ever, under all circumstances, to be preferred for facing valuable  
*copper plates* for printing.

According to the more or less careful adjustment of such  
plates in the press, many places of the facing are more or less  
attacked, and it may be desired to remove the coating and  
make a fresh deposit. For this purpose, Gaiffe has proposed  
the use of cobalt in place of nickel, because the former dis-  
solves slowly but completely in dilute sulphuric acid. He  
recommends a solution of 1 part of chloride of cobalt in 10 of  
water. The solution is to be neutralized with aqua ammonia,  
and the plates are to be electro-plated with the use of a mod-  
erate current.

Cobalt precipitated from its chloride solution, however, does  
not yield a hard coating, and hence the following bath is  
recommended for the purpose: Double sulphate of cobalt and  
ammonium 21 ozs., cobaltous carbonate 0.8 oz., crystallized  
boric acid  $10\frac{1}{2}$  ozs., water 10 quarts.

The bath is prepared in the same manner as No. VII., given  
under "Nickeling." It requires a tension of 2.5 to 2.75 volts;  
current-density, 0.6 ampère.

To determine whether copper, and how much of it, is dissolved  
in stripping the cobalt deposit from cobalted copper plates, a  
copper plate with a surface of  $7\frac{3}{4}$  square inches was coated with  
7.71 grains of cobalt and placed in dilute sulphuric acid (1 part  
acid of  $66^{\circ}$  Bé., to 12.5 parts of water). After the acid had acted  
for 16 hours, the cobalt deposit was partially dissolved and had  
partially collected in lamina upon the bottom of the vessel, the  
copper plate being entirely freed. On weighing the copper plate  
it was shown that it had lost about 0.0063 per cent., this loss

being apparently chiefly from the back of the plate, the engraved side exhibiting no trace of corrosion. This experiment proved that there is no danger of destroying the copper plate by stripping the cobalt deposit with dilute sulphuric acid, provided the operation is executed with due care and attention.

Warren has described a cobalt solution which can be decomposed in a single cell apparatus, and for this reason would seem suitable for electro-plating small articles *en masse*. For the preparation of this bath, dissolve  $3\frac{1}{2}$  ounces of chloride of cobalt in as little water as possible, and compound the solution with concentrated solution of Rochelle salt until the voluminous precipitate at first formed, is almost entirely redissolved, and then filter. Bring the bath into a vessel and place the latter in a clay cell filled with concentrated solution of sal ammoniac or of common salt, and containing a zinc cylinder. Connect the objects to be plated to the zinc by a copper wire and allow them to dip in the cobalt solution. With a closed circuit the objects become gradually coated with a lustrous cobalt deposit which, after 2 hours, is sufficiently heavy to bear vigorous polishing with the bob. Zinc may be coated in the same manner.

The following solution has been recommended by Mr. G. W. Beardslee, of Brooklyn, N. Y., and is claimed to yield a good deposit of cobalt which is very white, exceedingly hard, and tenaciously adherent: Dissolve pure cobalt in boiling hydrochloric acid and evaporate the solution to dryness. Next dissolve 4 to 6 ozs. of the resulting salt in 1 gallon of distilled water, to which add liquid ammonia until it turns red litmus-paper blue. The solution being thus rendered slightly alkaline, is ready for use. A battery power of from two to five Smee cells will be sufficient to do good work. Care must be had not to allow the solution to lose its slightly alkaline condition, upon which the whiteness, uniformity of deposit, and its adhesion to the basis-metal greatly depend.

For cobalting small fancy articles of copper, brass, or steel, R. Daub recommends the following bath: Dissolve  $4\frac{3}{4}$  ozs. of

double sulphate of cobalt and ammonium in  $4\frac{1}{2}$  quarts of water. The solution should show, at  $59^{\circ}$  F., a specific gravity of 1.015. The most suitable current-strength is 0.8 ampère with about two volts. The size of the anodes is of great influence as regards the uniformity of the cobalting. For the deposition of cobalt upon brass, copper, steel, or iron, the anodes may consist of rolled cobalt in strips about 2 inches wide and 10 to 12 inches long, according to the size of the articles. The anodes are arranged on the sides of the vat, about 6 inches apart. With the use of a large vat—holding from 500 to 1000 quarts of bath—a corresponding series of such anodes are to be suspended to a conducting rod which rests lengthwise upon the ends of the vat. The metallic articles should be coated with a thin film of cobalt in a few seconds after having been suspended in the bath, and the current-strength is then reduced, to be increased only when more articles are brought into the bath. The mode of treatment is different from that in the nickel bath, and, since cobalt deposits with greater ease than nickel, the regulation of the current is the principal point. The current-strength should be reduced as soon as the articles are entirely and nicely coated with cobalt. Copper articles require at the beginning a stronger current than brass objects, while for articles of iron or steel the current should be weaker than for either brass or copper. Places in relief should be kept as far as possible from the anodes to prevent blackening or burning. According to R. Daub, the principal condition for the success of the operation is to maintain a uniform density of the bath, either by the addition of water or of cobalt salt, as may be required. The color of the deposit is much influenced by the current-strength. Thus a deposit with 1 volt and a large anode-surface is not so white as one with two volts and a smaller anode-surface, about  $\frac{2}{3}$  of that of the cathode. Cast-brass is especially suitable for cobalting, as well as metallic articles which are kept in dry rooms or used for ornamental purposes.

*Cobalting by contact.*—While nickeling by contact with zinc



yields only incomplete results, the cobalting of copper and brass articles succeeds very well with the use of the following bath: Crystallized cobalt sulphate 0.35 oz., crystallized sal ammoniac 0.07 oz., water 1 quart. Heat the bath to between  $104^{\circ}$  and  $122^{\circ}$  F., and immerse the previously cleansed and pickled articles in the bath, bringing them in contact with a bright zinc surface not too small; for small articles a zinc sieve may be used. In 3 or 4 minutes the coating is heavy enough to bear vigorous polishing.

## CHAPTER VIII.

### DEPOSITION OF COPPER, BRASS AND BRONZE.

#### I. DEPOSITION OF COPPER.

*Properties of copper.*—Copper has a characteristic red color, and possesses strong lustre. It is very tenacious, may be rolled to thin lamina, and readily drawn into fine wire. The specific gravity of wrought copper is 8.95, and of cast 8.92. Copper fuses more readily than gold, but with greater difficulty than silver.

In a humid atmosphere containing carbonic acid, copper becomes gradually coated with a green deposit of basic carbonate. When slightly heated it acquires a red coating of cuprous oxide, and when strongly heated a black coating of cupric oxide with some cuprous oxide. Copper is most readily attacked by nitric acid, but is slowly dissolved when immersed in heated hydrochloric or sulphuric acid. With exclusion of the air, it is not dissolved by dilute sulphuric or hydrochloric acid, and but slightly with admission of the air. Liquid ammonia causes a rapid oxidation of copper in the air and the formation of a blue solution. An excess of potassium cyanide dissolves copper. Sulphuretted hydrogen blackens bright copper.

*Copper baths.*—The composition of these baths depends on the purpose they are to serve, and below are mentioned the most approved baths, with the exception of the acid copper bath used for plastic deposits of copper, which will be discussed later on under "Copper galvanoplasty."

In most cases the more electro-positive metals, zinc, iron, tin, etc., are to be coppered either as preparation for the succeeding process of nickeling, silvering, or gilding, or to protect them against oxidation, or for the purpose of decoration. The

above-mentioned electro-positive metals, however, decompose acid copper solutions and separate from them pulverulent copper, while an equivalent portion of zinc, iron, tin, etc., is dissolved. For this reason, such solutions cannot be used for coating these metals, and alkaline copper baths are exclusively employed, which may be arranged under two groups—those containing potassium cyanide, and those without it.

Hassauer prepares a copper bath by dissolving  $3\frac{1}{2}$  ozs. of copper cyanide in a solution of  $17\frac{1}{2}$  ozs. of 70 per cent. potassium cyanide in 3 quarts of water, boiling, filtering, and diluting with 7 quarts of water to a 10-quart bath. This bath works very well when heated to between  $113^{\circ}$  and  $122^{\circ}$  F., but when used cold requires a very strong current, and hence the use of the following formulæ is recommended:—

*Copper baths for iron and steel articles.*—I. *To be used at the ordinary temperature.*—Water 10 quarts, bisulphite of soda in powder 7 ozs., crystallized carbonate of soda 14 ozs., neutral acetate of copper 7 ozs., 75 per cent. potassium cyanide 7 ozs., spirits of sal ammoniac 4.4 ozs.

II. *For hot coppering (at between  $140^{\circ}$  and  $158^{\circ}$  F.).* Rose-leur recommends: Water 10 quarts, bisulphite of soda in powder  $2\frac{3}{4}$  ozs., crystallized carbonate of soda 7 ozs., neutral acetate of copper 7 ozs., 75 per cent. cyanide of potassium  $9\frac{3}{4}$  ozs., spirit of sal ammoniac 4 ozs.

The baths are best prepared as follows: Dissolve the bisulphite and carbonate of soda in one-half of the water, the potassium cyanide in the other half, and mix the copper salt with the spirit of sal ammoniac; then pour the blue ammoniacal copper solution into the solution of the soda salts, and finally add the potassium cyanide solution; the bath will then be clear and colorless. Boiling, though not absolutely necessary, is of advantage, after which the solution is to be filtered.

According to thorough investigations made, the excess of carbonate of soda in formula I. serves no special purpose, but on the contrary, in many cases, is directly detrimental; neither is the use of ammonia of any special advantage, and it may just

as well, or rather better, be omitted. Further, the use of separate baths for cold and warm coppering is at least questionable. It is believed that a single bath suffices for both cases, heating having been found of special advantage only for rapid and thick coppering, or for obtaining particular shades which are produced with difficulty in the cold bath, but without trouble in the heated bath.

The following formula may be highly recommended, a copper bath composed according to it always yielding good and sure results:—

III. Water 10 quarts, crystallized carbonate of soda  $8\frac{1}{2}$  ozs., crystallized bisulphite of soda 7 ozs., neutral acetate of copper 7 ozs., 98 or 99 per cent. potassium cyanide  $8\frac{1}{2}$  ozs.

The bath is prepared as follows: Dissolve in 7 quarts of warm water the carbonate of soda, *gradually* add the bisulphite of soda to prevent violent effervescence, and then add, with vigorous stirring, the acetate of copper in small portions. Dissolve the potassium cyanide in 3 quarts of cold water, and mix both solutions when the first is cold. By thorough stirring with a clean wooden stick a clear solution is quickly obtained which is allowed to settle and siphoned off clear. If after the addition of the potassium cyanide the bath should not become colorless, or at least wine-yellow, add a small quantity more of potassium cyanide. This bath does not require a strong current, and yields an especially heavy coppering of a beautiful red color. A current of 0.4 ampère at a tension of 3 to 3.5 volts is calculated for  $15\frac{1}{2}$  square inches of surface of objects. With a greater content of potassium cyanide the tension may be correspondingly decreased.

For coppering *zinc articles*, Roseleur recommends the following bath:—

IV. Water 10 quarts, tartar, free from lime, 6.7 ozs., crystallized carbonate of soda 15 ozs., blue vitriol 6.7 ozs., caustic soda lye of  $16^{\circ}$  Bé.  $\frac{3}{4}$  lb.

To prepare this bath, dissolve the tartar and the crystallized carbonate of soda in  $\frac{2}{3}$  of the water, and the blue vitriol in the



remaining  $\frac{1}{3}$ , and mix both solutions. Filter off the precipitate, dissolve it in the caustic soda lye, and add this solution to the other.

This bath works very well, and may be recommended to electro-platers who copper zinc exclusively; but where all kinds of metals are to be coppered, bath No. III. is to be preferred, it yielding equally good results for zinc.

For small zinc objects which are to be coppered in a sieve, bath No. III. is used, it being heated for this purpose, and a little more potassium cyanide added. Roseleur recommends for the same purpose a bath composed as follows:—

V. Water 10 quarts, neutral crystallized bisulphite of soda  $1\frac{3}{4}$  ozs., neutral acetate of copper 8 ozs., 75 per cent. potassium cyanide  $12\frac{1}{4}$  ozs., and ammonia  $\frac{1}{2}$  oz. The bath is prepared in the same manner as formulæ I. to III.

In preparing copper baths, the acetate of copper prescribed in the preceding formulæ may be replaced by the carbonate or sulphate, the substitution of the latter, after its previous conversion into carbonate, being of special advantage in order not to impart to the bath too great a resistance by the potassium sulphate, formed by reciprocal decomposition. The following formula is especially suitable for the use of sulphate of copper (blue vitriol):—

VI. Blue vitriol . . . . .	10½ ozs.
Crystallized carbonate of soda . . . . .	10½ “

---

Water . . . . .	10 quarts.
Pulverized bisulphite of soda . . . . .	7 ozs.
Crystallized carbonate of soda . . . . .	8½ ozs.
98 to 99 per cent. potassium cyanide . . . . .	8½ “

First dissolve the 10½ ozs. of blue vitriol and the 10½ ozs. of crystallized carbonate of soda, each by itself, in hot water, and mix the two solutions. Allow the precipitate of carbonate of copper to settle, and pour off the supernatant clear fluid. Then pour upon the precipitate 5 quarts of water, add the bisulphite of soda, next the carbonate of soda, and mix this

solution with the solution of the potassium cyanide in 5 quarts of water. The fluid rapidly becomes clear and colorless, when it is boiled and filtered.

In a recent formula cuprous oxide, which is found in commerce under the name of cupron, is used in place of cupric oxide.

VII. Cupron  $3\frac{1}{2}$  ozs., 99 per cent. potassium cyanide  $10\frac{1}{2}$  ozs., pulverized sodium bisulphite  $10\frac{1}{2}$  ozs., water 15 quarts.

Dissolve the potassium cyanide in one-half the prescribed quantity of water (cold), then gradually stir in the cupron, and after the solution of the latter, add the sodium bisulphite previously dissolved in the other half of the water.

In place of cupron, copper sulphite may be used. This salt dissolves in potassium cyanide without perceptible evolution of cyanogen, since it contains more than the sufficient quantity of sulphurous acid required for the reduction of the oxide salt present.

Suitable formulæ for baths with copper sulphite are as follows:

VIII. Ammonia-soda  $1\frac{2}{3}$  ozs., 99 per cent. potassium cyanide  $8\frac{1}{2}$  ozs., copper sulphite  $4\frac{1}{4}$  ozs., water 10 quarts; or,

IX. 60 per cent. potassium cyanide 14 ozs., copper sulphite  $4\frac{1}{4}$  ozs., water 10 quarts.

Dissolve the salts in the order given in 5 quarts of the water, stirring constantly, and then add the remaining 5 quarts of water.

The deposits obtained in these baths are of a beautiful warm color, very adherent and dense.

A bath recently recommended by the "Metallarbeiter" consists of potassium copper cyanide  $2\frac{3}{4}$  ozs., 99 per cent. potassium cyanide 1.12 drachms, crystallized sal ammoniac 1.12 drachms, ammonia-soda  $\frac{1}{3}$  oz., water 1 quart. With the exception of easy preparation by simply dissolving the salts, this bath has no advantage. It possesses, however, the disadvantage of all baths containing sal ammoniac when iron is the basis-metal, as has been already explained under "Nickeling."

According to the directions given the bath must be operated at  $68^{\circ}$  to  $75^{\circ}$  F., very likely for the reason that for want of sufficient and suitable conducting salts, the resistance at the ordinary temperature is quite great. However, the warming of the bath is another disadvantage.

Of the many directions for *copper baths without potassium cyanide*, to which also belongs the bath prepared according to formula IV., and which have chiefly been proposed for coppering cast and wrought iron, only a few need be mentioned as being actually available.

Weil obtains a deposit of copper in a bath consisting of a solution of blue vitriol in an alkaline solution of tartrate of potassium or sodium. Such a bath is composed as follows:—

X. Water 10 quarts, potassium sodium tartrate (Rochelle salt) 53 ozs., blue vitriol  $10\frac{1}{2}$  ozs., 60 per cent. caustic soda 28 ozs.

The chief purpose of the large content of caustic soda is to keep the tartrate of copper, which is almost insoluble in water, in solution. According to Weil, the coppering may be executed in three different ways, as follows:—

The iron articles tied to zinc wires or in contact with zinc strips are brought into the bath; the coppering thus taking place by contact. Or, porous clay cells are placed in the bath containing the articles, these clay cells are filled with soda lye in which zinc plates connected with the object-rods are allowed to dip, the arrangement in this case forming an element with which, by the solution of the zinc in the soda lye, a current is produced, which effects the decomposition of the copper solution and the deposition. When saturated with zinc the soda lye becomes ineffective, and, according to Weil, it may be regenerated by the addition of sodium sulphide, which separates the dissolved zinc as zinc sulphide. *The third method of coppering* consists in the use of the current of a battery or of a dynamo-machine, in which case copper anodes have, of course, to be employed.

A copper bath recommended by Walenn is composed of a

solution of equal parts of tartrate of ammonia and potassium cyanide, in which 3 to 5 per cent. of copper (in the form of blue vitriol or moist cupric hydrate) is dissolved. The bath is to be heated to about 140° F.

*Copper bath according to Pfanhauser.*—Dissolve 2¾ ozs. of cyanide of copper, 1⅛ drachms each of pure 100 per cent. potassium cyanide and crystallized sal ammoniac, and 5½ drachms of ammonia soda in 1 quart of lukewarm water, stirring constantly until all the salts are dissolved.

The temperature of the bath should be between 68° and 77° F., and the strength of current 3 volts. Density of current 0.5 ampère. In case the bath should become poor in metal, cyanide of copper has to be added. When the copper anodes become coated with too great an abundance of green slime, which does not decrease during the night when the bath is not working, some potassium cyanide, about ½ drachm per quart, should be added.

*Gauduin's copper bath* consists of a solution of oxalate of copper with oxalate of ammonia and free oxalic acid. Fontaine asserts that the bath works well, when heated to between 140° and 150° F.

Copper baths containing cyanide cannot be brought into pitched vats, vats of stoneware or enameled iron being used for smaller baths, and for larger, basins of brick set in cement, or iron reservoirs lined with ebonite. For large baths containing potassium cyanide wooden vats lined with lead can be used without disadvantage, since a slight coating of cyanide of lead, which may be formed upon the lead, is insoluble in potassium cyanide, and even if a small quantity of cyanide of lead would be dissolved in the bath by the presence of organic acids, a separation of lead besides copper upon the cathodes does not take place.

*Execution of copper-plating.*—The general rules given under nickeling, as regards the suitable composition of the bath, correct selection of anodes, careful scouring and pickling of the objects and proper current-strength also apply to copper-plating.



Annealed sheets of pure copper with as large a surface as possible serve as anodes. In all baths containing cyanide the anodes become, in a comparatively short time, coated with a greenish slime consisting of a basic copper cyanide mostly soluble in excess of potassium cyanide. When a very thick formation of such slime takes place, potassium cyanide is wanting, and has to be added. Other phenomena appearing in copper baths containing cyanide may as well here be mentioned. Too large an excess of potassium cyanide causes a strong evolution of hydrogen bubbles on the objects; but no deposition of copper, or only a slight one, takes place, which besides has the tendency to peel off. If this phenomenon appears after adding potassium cyanide, the excess can be readily removed by the addition of copper salt, best cyanide of copper, stirred with a small quantity of the bath to a thinly fluid paste and added to the bath with constant and long-continued stirring. After each addition, a test is made whether an object suspended in the bath is rapidly and regularly coppered; if such is not the case, the addition of cyanide of copper is repeated until the bath works in a faultless and correct manner. On the other hand, a deposit may not be formed for the want of potassium cyanide, which is already indicated by a thick formation of slime on the anodes, and by the fluid acquiring a pale blue color; or the metallic content of the bath may be too small. While in the first case a slight addition of potassium cyanide alone will cause the bath to work correctly, in the other case, an addition of solution of copper cyanide in potassium cyanide is required to augment the content of metal in the bath, it being best to introduce together with the metallic cyanide solution a small quantity of carbonate and bisulphite of soda, in order to decrease the resistance to conductivity. In place of solution of copper cyanide in potassium cyanide, commercial crystallized potassium copper cyanide may be used. In plating with a strong current the anodes become frequently coated to such an extent that finally no current passes into the bath, the excess of potassium cyanide being

unable to dissolve the copper cyanide as rapidly as it is formed. In this case scouring the anodes is the only remedy.

Many platers are of the opinion that the articles to be copper-plated do not require very careful cleaning and pickling before plating because this is sufficiently effected by the baths themselves, by those containing potassium cyanide, as well as by those with alkaline-organic combinations. This opinion, however, is wrong. It is true the potassium cyanide dissolves a layer of oxide, but not, or at least very incompletely, any grease present upon the articles, and hence it is advisable to free articles intended for coppering as thoroughly from grease as articles to be nickeled.

The preliminary scouring and pickling of the articles to be coppered are executed according to the directions given on p. 163. The same precautions referred to under "Nickeling" have to be used in suspending the objects in the bath, and the directions given there for the suitable arrangement of the anodes, etc., also apply to coppering. However, as a copper bath conducts better than a nickel bath, the distance between the anodes and the objects may, if necessary, be somewhat greater.

With a proper arrangement of the anodes and correct regulation of the current, the objects should be entirely coated with copper in a few minutes after being suspended in the bath. In five to ten minutes the objects are taken from the bath and brushed with a scratch-brush of not too hard brass wires, whereby the deposit should everywhere show itself to be durable and adherent. Defective places are especially thoroughly scratch-brushed, scoured, and pickled; the objects are then returned to the bath. For solid and heavy plating the objects remain in the bath until the original lustre and red tone of the coppering disappear and pass into a dull discolored brown. At this stage the objects are again scratch-brushed until they show lustre and the red copper color, whereby it is of advantage to moisten them with tartar water. They are then again returned to the bath, where they remain until the

dull discolored tone reappears. They are then taken out, scratch-brushed bright, rinsed in several clean waters, plunged into hot water, and finally dried, first in sawdust and then thoroughly, at a high temperature, in the drying chamber. Special attention must be paid to the thorough washing of the coppered objects, because, if anything of the bath containing cyanide remains in the depressions or pores, *small, dark, round stains* appear on those places, which cannot be removed, or at least only with great difficulty, they reappearing again in a short time after having been apparently removed. This formation of stains appears especially frequently upon coppered (as well as brassed) iron and zinc castings, which cannot be produced without pores. To prevent the formation of these stains the following method is recommended: Since the rinsing in many waters, and even allowing the objects to lie for hours in running water, offer no guarantee that every trace of fluid containing cyanide has been removed, the objects are brought into a slightly acid bath which decomposes the fluid, a mixture of 1 part of acetic acid and 50 parts of water being well adapted for the purpose. The objects are allowed to remain in this mixture for three to five minutes, when they are rinsed off in water and dipped for a few minutes in dilute milk of lime. They are finally rinsed off and dried. Coppered castings thus treated will show no stains.

O. Shultz obtained a patent for the following method for removing the hydrochloric acid from the pores, and thus preventing the formation of stains: The plated objects are placed in a room which can be hermetically closed. The air is then removed from the room by the introduction of steam of a high tension, and by means of an air-pump, and water sprinkled upon the objects. By this treatment in vacuum the fluid in the pores comes to the surface, and the salt solution is removed by the water sprinkled over the articles.

After drying, the deposit of copper, if it is to show high lustre, is polished with soft wheels of fine flannel and dry Vienna lime. Commercial rouge FFF, moistened with a little alcohol,

is also an excellent polishing agent for copper and all other soft metals.

As is well known, massive copper rapidly oxidizes in a humid atmosphere, and this is the case to a still greater extent with electro-deposited copper. Hence, the coppered objects, if they are not to be further coated with a non-oxidizing metal, have to be provided with a colorless, transparent coat of lacquer (see "Lacquering").

It frequent happens that slightly coppered (as well as slightly brassed) objects, especially of zinc, after some time, become entirely white and show no trace of the deposit. This is due to the deposit penetrating into the basis-metal, as already explained. Lacquering in this case is of no avail, the deposit also disappearing under the coat of lacquer. The only remedy against this phenomenon is a heavier deposit.

If the coppered objects are to be coated with another metal, drying is omitted, and after careful rinsing they are directly brought into the respective bath, or into the quicking pickle, if, as, for instance, in silvering, quicking has to be done. In such cases, where the copper deposit serves only as an intermediary for the reception of another metallic coating, the objects need not to be coppered as thickly, as previously described, by treating them three times in the bath. Preliminary coppering for 5 to 10 minutes suffices in all cases, which is succeeded by scratch-brushing in order to be convinced that the deposit adheres firmly and that the basis-metal is uniformly coated. The objects are then suspended in the bath for 5 to 10 minutes longer with a weak current.

In *coppering sheet iron* or *sheet zinc* which is to be nickeled, the sheets are taken from the bath after 3 to 5 minutes, at any rate while they still retain lustre, scratch-brushing being in this case omitted. For coppering such sheets a current-density of 0.5 ampère with a tension of 3.5 to 4 volts is required.

The treatment of copper baths when they become inactive and other abnormal phenomena have already been referred to. All other rules for electro-plating baths given in Chapter VI. must here also be observed.



For coppering *small articles en masse* in sieves, it is recommended to have the copper baths quite hot; for the rest, the process is the same as that given for nickeling small articles *en masse*.

*Coppering by contact and dipping.*—According to Lüdersdorff, a solution of tartrate of copper in neutral potassium tartrate serves for this purpose. A suitable modification of this bath is as follows: Heat 10 quarts of water to 140° F., add 2 lbs. of pulverized tartar (cream of tartar) free from lime, and 10½ ozs. of carbonate of copper. Keep the fluid at the temperature above mentioned until the evolution of gas due to the decomposition of the carbonate of copper ceases, and then add in small portions, and with constant stirring, pure whiting until effervescence is no longer perceptible. Filter off the fluid from the tartrate of lime, separate and wash the precipitate, so that the filtrate, inclusive of the wash water, amounts to 10 or 12 quarts.

Zinc is coppered in this bath by simple immersion; other metals have to be brought in contact with zinc.

*To coat zinc plates with a very thin but hard layer of copper,* immerse the plates in a bath composed of 100 parts of water saturated with cupric chloride—cupric chloride 40 parts, water 60—150 parts of ammonia and 3000 parts of water. For very solid coppering, the above-described bath, which is of a beautiful blue color, is used, and a saturated solution of potassium cyanide in water added until the blue of the first mixture has quite disappeared. For plates engraved with the burin or for stamped plates, it is best to use a mixture of cyanide of copper with neutral potassium sulphate, to which is added a mixture of a saturated solution of blue vitriol in water and of water saturated with cyanide of copper. The bath is ready for use when the precipitate is completely dissolved and the fluid entirely discolored.

Another contact coppering bath is that prepared according to formula X., proposed by Weil. In this bath zinc is also coppered by simple immersion, and copper and iron in contact with zinc strips.

According to Bacco, a copper bath in which zinc may be coppered by immersion, and iron and other metals in contact with zinc, is prepared by adding to a saturated solution of blue vitriol, potassium cyanide solution until the precipitate of cyanide of copper which is formed is again dissolved. Then add  $\frac{1}{10}$  to  $\frac{1}{5}$  of the volume of liquid ammonia and dilute with water to 8° Be.

The so-called *brush-coppering*, which has been recommended, may here be mentioned. This process may be of practical advantage for coppering very large objects which by another method could only be coated with difficulty. The deposit of copper is, of course, very thin. The process is executed as follows: The utensils required are two vessels of sufficient size, each provided with a brush, preferably so wide that the entire surface of the object to be treated can be coated with one application. One of the vessels contains a strongly saturated solution of caustic soda, and the other a strongly saturated solution of blue vitriol. For coppering, the well-cleansed object is first uniformly coated with a brushful of the caustic soda solution, and then also with a brushful of the blue vitriol solution. A quite thick film of copper is immediately deposited upon the object. Care must be had not to have the brush too full, and not to touch the places once gone over the second time, as otherwise the layer of copper does not adhere firmly.

Many iron and steel objects are provided with a thin film of copper in order to give them a more pleasing appearance. For this purpose a copper solution of 10 quarts of water, 1  $\frac{3}{4}$  ozs. of blue vitriol, and 1  $\frac{3}{4}$  ozs. of pure concentrated sulphuric acid may be used. Dip the iron or steel objects, previously freed from grease and oxide, for a moment in the solution, moving them constantly to and fro; then rinse them immediately in ample water, and dry. By keeping the articles too long in the solution the copper separates in a pulverulent form, and does not adhere.

Steel pens, needles' eyes, etc., may be coppered by diluting the copper solution just mentioned with double the quantity of

water, moistening sawdust with the solution and revolving the latter, together with the articles to be coppered, in a wooden tumbling barrel (p. 139).

The *inlaying* of depressions of coppered art-castings with black may be done in different ways. Some blacken the ground by applying a mixture of spirit lacquer with lampblack and graphite, while others use oil of turpentine with lampblack and a few drops of copal lacquer. A very thin nigrosin lacquer mixed with finely pulverized graphite is very suitable for the purpose. When the lacquer is dry the elevated places which are to show the copper color are cleansed with a linen rag moistened with alcohol.

Electrolytically coppered articles may be inlaid black by coating them, after thorough scouring and pickling, with arsenic in one of the baths given under "Electro-deposition of Arsenic," and, after drying in hot water and sawdust, freeing the surfaces and profiles, which are to appear coppered, from the coating of arsenic by polishing upon a felt wheel. If this polishing is to be avoided, the portions which are not to be black may be coated with stopping-off varnish, and arsenic deposited upon the places left free.

For *coloring, platinizing, and oxidizing of copper*, see the proper chapter.

#### *Examination of Copper-baths Containing Potassium Cyanide.*

In the preceding sections several characteristic indications which serve for the qualitative examination of these baths have already been given. Like all baths containing potassium cyanide, their original composition gradually suffers extensive alterations by the decomposition of the potassium cyanide, which by the carbonic acid of the air is changed to potassium carbonate and hydrogen cyanide, and spontaneously also to ammonia and potassium formate. The potassium cyanide is also split up by the current, potassium hydroxide being formed, together with decomposition of water, which by the carbonic acid of the air is gradually converted into potash,

while hydrogen cyanide and hydrogen escape. Under certain conditions an oxidation of the potassium cyanide to potassium cyanate also takes place.

The excess of potassium cyanide required for the correct performance of the copper-bath is therefore gradually consumed, and the bath, at first of a wine-yellow color, acquires a blue coloration, and does no longer yield a good deposit. When such is the case the same quantity of copper which is withdrawn from the bath by the deposit, is not dissolved from the anodes and, hence, the determination of the content of free potassium cyanide as well, as that of the content of copper, may at times be necessary. A determination of the potassium carbonate (potash) formed in the bath and its removal, or conversion into potassium cyanide by the addition of the corresponding quantity of barium cyanide solution, which will be referred to under silver baths, cannot be recommended, because this determination in copper baths which contain, as is generally the case, sulphides, is troublesome, and because an accumulation of potash in copper baths does not produce the same evils as in a silver bath. If, however, a copper bath, after working for years, has become thick in consequence of a large content of potash, it can be renewed without considerable expense, or, if this is not desired, it can be regenerated by diluting with water and increasing the content of copper and of potassium cyanide.

Hence, the determination of the free potassium cyanide (*i. e.*, not fixed on copper), and that of the copper will here only be discussed.

*Determination of potassium cyanide.*—The best and most rapid method for this purpose is by titrating with decinormal solution of silver nitrate. Silver nitrate and potassium cyanide form finally potassium nitrate and insoluble silver cyanide, the latter, however, being redissolved to potassium silver cyanide so long as free potassium cyanide is present. Since potassium silver cyanide contains two molecules of cyanogen, one molecule of silver nitrate corresponds to two molecules of potassium



cyanide and 1 cubic centimeter of decinormal solution of silver nitrate corresponds to 0.013 gramme of potassium cyanide.

Bring, by means of a pipette, 5 cubic centimeters of the copper bath into a beaker having a capacity of about  $\frac{1}{4}$  liter. Dilute with about 150 cubic centimeters of water, add one or two drops of saturated common salt solution, and then, whilst constantly stirring the fluid in the beaker, allow to flow in from the burette silver nitrate solution so long as the precipitate formed dissolves rapidly.

When solution becomes sluggish add, stirring constantly, silver nitrate solution drop by drop, waiting after the addition of each drop until the fluid has again become clear. When the fluid does not become clear after adding the last drop, and it shows a slight turbidity, no more free potassium cyanide is present. By multiplying the cubic centimeters of decinormal solution of silver nitrate used by 2.6, the content of potassium cyanide per liter of bath is found.

Suppose for 5 cubic centimeters of bath, 8.2 cubic centimeters of silver solution have been used, then one liter of the bath contains  $8.2 \times 2.6 = 21.32$  grammes of free potassium cyanide, because 1 cubic centimeter of silver solution corresponds to 0.013 gramme of potassium cyanide, therefore, 8.2 cubic centimeters = 8.2.  $0.013 = 0.1066$  grammes, from which results by calculation

$$\begin{aligned} 5 : 0.1066 &= 1000 : x \\ x &= 21.32 \text{ grammes.} \end{aligned}$$

If now the initial content of free potassium cyanide in the freshly-prepared bath had been determined, a later determination will show the deficiency of it which has taken place. It must, however, be taken into consideration that the potassium formate formed by the decomposition of the potassium cyanide may, up to a certain degree, apparently fill the role of the potassium cyanide, in so far as it decreases the conducting resistance of the bath, but it does not contribute to the solution of the anodes. Hence, if the established deficiency of potassium cyanide would be replaced by equally large quantities of

the salt, there would be danger of too much of it getting into the bath, and the latter would conduct too readily, which would result in the deposit precipitating too rapidly and turning out less adherent.

Hence, it is evident that analytical methods alone are not sufficient for maintaining entirely constant baths containing potassium cyanide, and practical experience and a good faculty of observation are required if the results of analysis are to be utilized for the correction of the baths. The potassium formate can neither be removed from the bath nor can it be quantitatively determined, and since its action in the bath is not accurately known, it can only be stated, from practical experience, that under normal conditions only about 60 per cent. of the deficiency of free potassium cyanide in a copper bath should be replaced by pure potassium cyanide.

*Determination of copper.* This may be effected by electrolytic or volumetric analysis.

*For the determination of copper by electrolysis,* measure off by means of the pipette 10 cubic centimeters of the copper bath, and allow the fluid to run into a porcelain dish having a capacity of 150 to 200 cubic centimeters. Add 10 cubic centimeters of pure strong hydrochloric acid, cover the dish with a watch glass, and heat upon the water bath. When evolution of gas ceases, carefully remove the watch glass, rinse off adhering drops with a small quantity of distilled water into the dish, and evaporate the contents of the latter nearly to dryness. Now add about 1 cubic centimeter of strong nitric acid, swing the dish so that all portions of the residue are moistened by the acid, heat for a short time, and then add 32 cubic centimeters of pure dilute sulphuric acid (1 part acid, 2 parts water), with which the contents of the dish are heated, until every trace of odor of hydrochloric and nitric acids has disappeared. Now pour the copper solution into the platinum dish serving for electrolysis, rinse the porcelain dish with distilled water, adding the wash-water to the contents of the platinum dish, fill the latter up to within 1 centimeter of the rim with water, add 2 cubic

centimeters of pure concentrated nitric acid and electrolyze with a current-strength of  $ND\ 100 = 1$  ampère, *i. e.*, 1 ampère for 100 square centimeters surface of the platinum dish which serves as cathode.

The copper separates with a bright red color, adhering firmly to the platinum dish which is connected with the negative pole of the source of current. That the separation of copper is finished is recognized by a narrow strip of platinum sheet, when suspended in the platinum dish, showing in 15 minutes no trace of coppering; or by a few drops of the solution when brought together with a drop of yellow prussiate of potash solution producing no red coloration.

When by one of the above mentioned means the complete separation of the copper has been ascertained, the platinum dish is washed, without interruption of the current, the water removed by rinsing the dish with absolute alcohol, and the latter removed by rinsing with ether. Dry for a short time in an air bath at  $212^{\circ}$  F., and weigh the dish together with the precipitate of copper. By deducting the weight of the dish, the weight of the copper is obtained, and, since 10 cubic centimeters of the bath were electrolyzed, the weight of the copper multiplied by 100 gives the contents of copper in grammes in 1 liter of copper bath.

*The volumetric determination of copper* is based upon the principle that solution of sulphate or chloride of copper forms, with potassium iodide, copper iodide, whilst free iodine is at the same time formed, one atom of liberated iodine corresponding to one molecule of copper salt. This free iodine is determined by titration with a solution of sodium hyposulphite of known content, and the content of copper is calculated from the number of cubic centimeters of the solution used. For the recognition of the final reaction, the blue coloration, which originates when starch solution combines with free iodine is utilized. There are required a decinormal iodine solution which contains per liter exactly 12.7 grammes of re-sublimated iodine dissolved in potassium iodide, and a decinormal solution

of sodium hyposulphite of which 10 cubic centimeters diluted with water and compounded with a small quantity of starch solution must exactly use 10 cubic centimeters of iodine solution to give a permanent blue coloration by the formation of iodine-starch.

The mode of operation is as follows: Heat in a porcelain dish 10 cubic centimeters of the copper bath with 10 cubic centimeters of strong hydrochloric acid, evaporate nearly to dryness with 1 cubic centimeter of strong nitric acid and 2 cubic centimeters of hydrochloric acid, and heat upon the water bath until the nitric acid is entirely removed. The residue is dissolved in water with the addition of a small quantity of dilute hydrochloric acid. The clear solution is brought into a measuring flask holding 100 cubic centimeters, the dish is rinsed with water, the free acid neutralized by the addition of dilute soda lye until a precipitate of bluish copper hydrate commences to separate, which after vigorous shaking does not disappear. Now add, drop by drop, hydrochloric acid until the precipitate just dissolves, fill the flask up to the 100 centimeter mark with water, and mix by shaking. Of this solution bring by means of the pipette 10 cubic centimeters into a glass of 100 cubic centimeters capacity and provided with a glass stopper, add 10 cubic centimeters of a 10 per cent. potassium iodide solution, dilute with a small quantity of water, close the glass with the stopper, and let it stand for 10 minutes. Now add from a burette decinormal solution of sodium hyposulphite until the iodine solution has become colorless, and then add a few cubic centimeters more. Next bring into the flask a few drops of starch solution, and then add from another burette decinormal iodine solution until a blue coloration is just apparent. By deducting the cubic centimeters of iodine solution used from the cubic centimeters of sodium hyposulphite solution, it will be known how many cubic centimeters of the latter solution have been used for fixing the iodine liberated by the reciprocal action between copper solution and potassium cyanide solution. Since 1 cubic centimeter of a sodium hypo-



sulphite solution, which is equivalent to the decinormal iodine solution, corresponds to 0.0063 gramme of copper, therefore, as 1 cubic centimeter of the bath has been titrated, the number of cubic centimeters found has to be multiplied by 6.3 to find the content of copper per liter of copper bath.

Suppose to 10 cubic centimeters of the copper solution mixed with potassium iodide had been added 2.8 cubic centimeters of sodium hyposulphite solution, and for titrating back the excess 0.7 cubic centimeter of iodine solution had been used up to the appearance of the blue coloration, then  $2.8 - 0.7 = 2.1$  centimeters have been used, which multiplied by 6.3 gives 13.3 grammes as the content of copper per liter of bath.

If now a deficiency of copper has been established by one or the other method, the original content of copper can be readily restored by the addition of crystallized potassium copper cyanide. This salt, when pure, contains about 30 per cent. copper.

Suppose, when first prepared, the bath contained 15 grammes of copper per liter, and it has been shown by analysis that it contains only 13.3 grammes, then a deficiency of 1.7 grammes of copper has to be made up. Since 100 grammes of potassium copper cyanide contain 30 grammes of copper, then

$$\frac{30 : 100 = 1.7 : x}{x = 3.57,}$$

and hence 3.57 grammes of potassium copper cyanide per liter have to be dissolved in the bath.

## 2. DEPOSITION OF BRASS (*Cuivre-poli Deposit*).

Brass is an alloy of copper and zinc, whose color depends on the quantitative proportions of both metals. The alloys known as *yellow brass*, *red brass* (*similar, tombac*), consist essentially of copper and zinc, while those known as *bell metal*, *gun metal* and the *bronzes* of the ancients are composed of copper and tin. *Modern bronzes* contain copper, zinc and tin.

The behavior of brass towards acids is nearly the same as that of copper. It oxidizes, however, less readily in the air, is

harder than copper, malleable, and can be rolled and drawn into wire.

*Brass baths.*—According to the plan pursued in this work only the most approved formulæ, the greater portion of which has been practically tested, will be given. There exist a large number of directions for brass baths; but we share the opinion of Roseleur, that a brass bath containing copper and zinc salts in nearly equal proportions is the most suitable and least subject to disturbances. A brass bath is to be considered as a mixture of solutions of copper cyanide and zinc cyanide, or of other copper-zinc salts in the most suitable solvent; and since a solution of copper cyanide requires a different current-strength from one of zinc salt, it will be seen that according to the greater or smaller current-strength, now more of the one, and now more of the other, metal is deposited, which, of course, influences the color of the deposit. Hence the proper regulation of the current is the chief condition for obtaining beautiful deposits, let the bath be composed as it may.

For all baths containing more than one metal in solution, it may be laid down as a rule that the less positive metal is first deposited. In a brass bath copper is the negative, and zinc the positive, metal; and hence a *weaker* current deposits more copper, in consequence of which the deposit becomes redder, while, *vice versa*, a *more powerful* current decomposes besides the copper solution also a larger quantity of zinc solution and reduces zinc, the color produced being more pale yellow to greenish. By bearing this in mind it is not difficult to obtain any desired shades within certain limits.

I. *Brass bath according to Roseleur.*—Blue vitriol and zinc sulphate (white vitriol), of each  $5\frac{1}{4}$  ounces, and crystallized carbonate of soda  $15\frac{3}{4}$  ounces. Crystallized carbonate of soda and crystallized bisulphite of soda, of each 7 ounces, 98 per cent. potassium cyanide  $8\frac{3}{4}$  ounces, arsenious acid  $30\frac{3}{4}$  grains, water 10 quarts.

The bath is prepared as follows: In 5 quarts of warm water dissolve the blue vitriol and the zinc sulphate; and in the other

5 quarts the  $15\frac{3}{4}$  ounces of carbonate of soda; then mix both solutions, stirring constantly. A precipitate of carbonate of copper and carbonate of zinc is formed, which is allowed quietly to settle for 10 to 12 hours, when the supernatant clear fluid is carefully poured off, so that nothing of the precipitate is lost. Washing the precipitate is not necessary. The clear fluid poured off is of no value and is thrown away. Now add to the precipitate so much water that the resulting fluid amounts to about 6 quarts, and dissolve in it, with constant stirring, the carbonate and bisulphite of soda, adding these salts, however, not at once, but gradually, in small portions, to avoid foaming over by the escaping carbonic acid. Dissolve the potassium cyanide in 4 quarts of cold water and add this solution, with the exception of about  $\frac{1}{2}$  pint, in which the arsenious acid is dissolved with the assistance of heat, to the first solutions, and finally add the solution of arsenious acid in the  $\frac{1}{2}$  pint of water retained, when the bath should be clear and colorless. If after continued stirring, particles of the precipitate remain undissolved, carefully add somewhat more potassium cyanide until solution is complete.

Fresh brass baths work, as a rule, more irregularly than any other baths containing cyanide, the deposit being either too red or too green or gray, while frequently one side of the object is coated quite well, and the other not at all. To force the bath to work correctly it must be thoroughly boiled, the water which is lost by evaporation being replaced by the addition of distilled water or pure rain water. If boiling is to be avoided, the bath, as previously mentioned, is worked through for hours, and even for days, with the current, until an object suspended in it is correctly brassed.

The addition of a small quantity of arsenious acid is claimed to make the brassing brighter; but the above-mentioned proportion of  $30\frac{3}{4}$  grains for a 10 quart bath must not be exceeded, as otherwise the color of the deposit would be too light and show a gray tone.

II. Crystallized carbonate of soda  $10\frac{1}{2}$  ounces, crystallized

bisulphite of soda 7 ounces, neutral acetate of copper 4.4 ounces, crystallized chloride of zinc 4.4 ounces, 98 per cent. potassium cyanide 14.11 ounces, arsenious acid  $30\frac{3}{4}$  grains, water 10 quarts.

The preparation of this bath is more simple than that of the preceding.

Dissolve the carbonate and bisulphite of soda in 4 quarts of water, then mix the acetate of copper and chloride of zinc with 2 quarts of water, and gradually add this mixture to the solution of the soda salts. Next dissolve the potassium cyanide in 4 quarts of water, and add this solution to the first, retaining, however, a small portion of it, in which dissolve the arsenious acid with the assistance of heat. Finally add the arsenious acid solution, when the bath will become clear. Boiling the bath, or working it through with the current, is also required.

For brassing *iron* in this bath, the quantity of carbonate of soda may be increased up to 35 ozs. for a 10-quart bath. This is also permissible, when in plating zinc articles with a heavy deposit of brass, frequent scratch-brushing is to be avoided. It would seem that a large content of carbonate of soda in the bath retards to a considerable extent the brass color from changing into a discolored brown, though the brilliancy of the deposit appears to suffer somewhat. When boiled for 1 to 2 hours, or worked through with the current for 10 to 12 hours, the bath prepared according to formula II. works very well. It requires a current of 0.5 to 0.55 ampère, with a tension of 3.5 to 4 volts per  $15\frac{1}{2}$  square inches of surface.

Cuprous sulphide, mentioned under copper baths, may also be advantageously used for the preparation of brass baths, a suitable formula being as follows:

III. Pure crystallized zinc sulphate (zinc vitriol or white vitriol)  $5\frac{1}{2}$  ozs., crystallized carbonate of soda  $7\frac{3}{4}$  ozs., neutral crystallized bisulphite of soda  $9\frac{3}{4}$  ozs., ammonia-soda  $1\frac{1}{2}$  ozs., 99 per cent. potassium cyanide 3 ozs., cuprous sulphide 3 ozs., water 10 quarts.

The bath is prepared as follows: Dissolve the zinc sulphide



in 5 quarts of the water, and the carbonate of soda in 4 quarts of warm water, and mix the two solutions. When the precipitate of zinc carbonate, which is formed, has completely settled, siphon off the supernatant fluid as much as possible, add 5 quarts of water, and then the ammonia-soda. In the other 5 quarts of water dissolve the potassium cyanide and the neutral bisulphide of soda, stir in the cuprous sulphide, and when solution is complete, add this solution to the first, when by vigorous stirring the carbonate of zinc will also dissolve.

This bath yields beautiful pale yellow deposits of a warm brass tone.

IV. Crystallized carbonate of soda  $10\frac{1}{2}$  ozs., crystallized bisulphite of soda 7 ozs., copper cyanide and zinc cyanide of each  $3\frac{1}{2}$  ozs., water 10 quarts, and enough 98 per cent. potassium cyanide to render the solution clear.

To prepare the bath dissolve the carbonate and bisulphite of soda in 2 to 3 quarts of water, rub in a porcelain mortar the copper cyanide and zinc cyanide with a quart of water to a thin paste, add this paste to the solution of the soda salts, and finally add, with vigorous stirring, concentrated potassium cyanide solution until the metallic cyanides are dissolved. Dilute the volume to 10 quarts, and, for the rest, proceed as given for formulas I. and II.

For *brassing zinc* exclusively, Roseleur recommends the following bath:

V. Dissolve  $9\frac{3}{4}$  ozs. of crystallized bisulphite of soda and 14 ozs. of 70 per cent. potassium cyanide in 8 quarts of water, and add to this solution one of  $4\frac{3}{4}$  ozs. each of neutral acetate of copper and crystallized chloride of zinc,  $5\frac{1}{2}$  ozs. of aqua ammonia, and 2 quarts of water.

For *brassing cast-iron, wrought-iron, and steel*, Gore highly recommends the following composition:—

VI. Dissolve  $35\frac{1}{4}$  ozs. of crystallized carbonate of soda, 7 ozs. of crystallized bisulphite of soda,  $13\frac{1}{4}$  ozs. of 98 per cent. potassium cyanide in 8 quarts of water; then add, with constant stirring, a solution of fused chloride of tin  $3\frac{1}{2}$  ozs., and

neutral acetate of copper  $4\frac{1}{4}$  ozs., in 2 quarts of water. Boil and filter. This bath works best with a current of 3.75 volts.

According to Norris and Johnson, a good brass bath is said to be obtained as follows:—

VII. Carbonate of ammonia  $35\frac{1}{4}$  ozs., 70 per cent. potassium cyanide  $35\frac{1}{4}$  ozs., copper cyanide and zinc cyanide each  $2\frac{1}{4}$  ozs., water 10 quarts.

The large content of potassium cyanide in this bath is unintelligible.

A solution for *transferring any copper-zinc alloy which serves as anode* is composed, according to Hess, as follows:—

VIII. Bisulphite of soda  $14\frac{3}{4}$  ozs., crystallized sal ammoniac  $9\frac{1}{2}$  ozs., 98 per cent. potassium cyanide  $2\frac{1}{2}$  ozs., water 10 quarts.

Cast metal plates are to be used as anodes. The transfer begins after a medium strong current, has for a few hours, passed through the bath. This bath is also well adapted for the deposition of tombac, with the use of tombac anodes. Most suitable current-tension, 3 to 3.5 volts.

IX. For brassing all kinds of metals and large as well as small objects, Pfanhauser recommends the following bath: Water 10 quarts, calcined carbonate of soda 5 ozs., calcined sulphate of soda 7 ozs., acid sodium sulphite 7 ozs., potassium copper cyanide 7 ozs., potassium zinc cyanide 7 ozs., 100 per cent. potassium cyanide 0.35 oz., ammonium chloride 0.7 oz.

The bath is prepared as follows: Pour one-half of the quantity of water (cold) into the tank intended for the reception of the brass bath. Dissolve, stirring vigorously, the carbonate and sulphate of soda in five times their quantity of warm water ( $122^{\circ}$  F.), and pour the solution into the tank. Dissolve the acid sodium sulphite in five times its quantity of warm water ( $122^{\circ}$  F.), stirring constantly, pour the solution slowly into the tank and stir until effervescence caused by mixing the two solutions ceases. The potassium copper cyanide, potassium zinc cyanide and potassium cyanide are together dissolved in five times their quantity of warm water ( $122^{\circ}$  F.) and added

to the solution in the tank, stirring constantly. Finally dissolve the ammonium chloride in  $12\frac{1}{2}$  times its quantity of water, pour the solution into the vat, and mix thoroughly by stirring. When all the salts are dissolved, the bath is ready for use.

The temperature of the bath should be between  $68^{\circ}$  and  $77^{\circ}$  F. For brassing zinc the current should have a strength of  $2\frac{1}{2}$  volts, for iron 3 volts, for chains 3 to  $3\frac{1}{2}$  volts, and for small articles *en masse* 4 volts. Density of the current, 0.5 ampère.

Brassing in this bath succeeds equally well with all kinds of metals, the result being a uniform deposit of metal while the color, even of thick deposits, is a fiery sad yellow. Small articles, which are suspended *en masse* in dipping baskets, as well as steel chains, and even cast-iron, which is notoriously difficult to brass, become rapidly coated in this bath. In case the brass anodes become coated with too great an abundance of green slime, which decreases during the night when the bath is not working, some potassium cyanide, about  $1\frac{1}{2}$  drachms per quart, should be added. The bath must, of course, be from time to time supplied with additions of fresh potassium copper cyanide and potassium zinc cyanide.

Brass baths containing potassium cyanide cannot be kept in pitched wooden tanks, as the pitch is dissolved by the salt.

*Execution of brassing.*—The most suitable current-density for this purpose is 0.6 to 0.7 ampère, at 3 to 4 volts.

As previously mentioned, the color of the deposits depends on the proportional quantity in which copper and zinc are present, a strong current depositing more zinc and a weak current more copper. By diminishing or increasing the current-strength by means of the resistance board, a deposit of a redder or more pale yellow to greenish color can be produced. However, with a bath which does not contain copper and zinc in the correct proportional quantities, and especially with old baths long in use, a determined color of the deposit cannot be produced with the assistance of the resistance board. In such case the content of the metal lacking in the bath, which is re-

quired for the production of a determined color, must be augmented by the addition of solution of the respective metallic salt in potassium cyanide.

Suppose a bath which originally contained copper and zinc salts in equal proportions has been long in daily use. Now, since brass contains more copper than zinc, it is evident that more of the former will be withdrawn from the bath than of the latter, and finally a limit will be reached when the bath with a current suitable for the decomposition of the solution will deposit a greenish or gray brass, and with a weaker current produce no deposit whatever. The only help in such a case is the addition of sufficient solution of copper cyanide in potassium cyanide, so that, even with quite a powerful current, a deposit of a beautiful brass color is produced, the shades of which can then again be controlled with the help of the resistance board. However, it must not be forgotten that every addition of a metallic salt momentarily irritates the brass bath, making it, so to say, sick, and to confine this phenomenon to the narrowest limit, an addition of carbonate and bisulphite of soda should at the same time be made, and the bath be worked through with the current as previously described, until a test shows that it works in a regular manner.

Annealed sheets of brass not rolled too hard, and of as nearly as possible the same composition and color the deposit is to show, are used as anodes. The anode-surface should be at least twice as large as that of the objects to be brassed, though it is best to use as many anodes as the anode-rods will hold.

As in the copper bath, an abundant formation of slime on the anodes indicates the want of potassium cyanide in the bath. In this case the evolution of gas bubbles on the objects is very slight, and the deposit forms slowly. This is remedied by an addition of potassium cyanide. The slow formation of the deposit, however, may also be due to a want of metallic salts. In this case not only potassium cyanide, but also solution of copper cyanide and zinc cyanide in potassium cyanide, has to be added. For this purpose prepare a concentrated solution



of potassium cyanide in water, and a solution of equal parts of blue vitriol and zinc sulphate in water. From the latter precipitate the copper and zinc as carbonates with a solution of carbonate of soda, as given in formula I., p. 281. After allowing the precipitate to settle, pour off the clear supernatant fluid, and add to the precipitate, with vigorous stirring, of the potassium cyanide solution, until it is dissolved; if heating takes place thereby, add from time to time a little cold water. Add this solution with a small excess of potassium cyanide, and the addition of carbonate or bisulphite of soda, to the bath, and boil the latter or work it through with the current. A more simple method is to procure copper cyanide and zinc cyanide, or concentrated solutions of these combinations, from a dealer in such articles. In the first case rub in a mortar equal parts of zinc cyanide and copper cyanide with water to a thickly fluid paste. Pour this paste into potassium cyanide solution, containing about 7 ozs. of potassium cyanide to the quart, as long as the metallic cyanides dissolve quite rapidly by stirring. When solution takes place but slowly, stop the addition of paste.

When a brass bath contains too large an excess of potassium cyanide, a very vigorous evolution of gas takes place on the objects, but the deposit is formed slowly or not at all; besides, the deposit formed has a tendency to peel off in scratch-brushing. In this case the injurious excess has to be removed, which is effected by pouring, whilst stirring vigorously, a quantity of the above-mentioned thinly fluid paste of zinc cyanide and of copper cyanide into the bath.

To avoid unnecessary repetition we refer, as regards the production of thick deposits, scratch-brushing and polishing of the plated articles, to what has been said under "Execution of Coppering," the directions given there being also valid for brassing.

The deposition of several metals from a common solution is not an easy task, and requires attention and experience. If, however, the directions given in this chapter are followed, the

operator will be able to conduct, after short experience, the brassing process with the same success as one in which but one metal is deposited.

In brassing, the distance of the objects to be plated from the anodes is of considerable importance. If objects with deep depressions or high reliefs are suspended in the brass bath, it will be found that, with the customary distance of  $3\frac{3}{4}$  to  $5\frac{3}{4}$  inches from the anodes, the brassing of the portions in relief nearest to the anodes will turn out a lighter color than that of the depressed portions, which will show a redder deposit, the reason for this being that the current acts more strongly upon the portions in relief, and consequently deposits more zinc than the weaker current, which strikes the depressions. To equalize the difference, the objects have to be correspondingly further removed from the anodes, with lamp-feet up to  $9\frac{3}{4}$  inches, and even more, when a deposit of the same color will be everywhere formed.

The brassing of unground *iron-castings* is especially troublesome, and in order to obtain a beautiful and clean deposit the preliminary scratch-brushing has to be executed with special care; but even then the color of the brass deposit will sometimes be found to possess a disagreeable gray tone. This is very likely largely due to the quality of the iron itself, and it is advisable first to give the casting a thin coat of nickel or tin, upon which a deposit of brass of the usual brilliancy can be produced. In baths serving for brassing iron articles, a large excess of potassium cyanide must be avoided. It is, however, an advantage to increase the content of carbonate of soda.

*Brassing by contact and dipping.*—Some authors have given directions for brassing by contact—for instance, Bacco, Weil, and others—but the results obtained are so unsatisfactory, and the process so uncertain, that it is not necessary to enter into further details.

The inlaying with black of brassed articles is done in the same manner as described under "Coppering."

For oxidizing, platinizing, and coloring of brass, see the proper chapter.

*Examination of brass baths.* The characteristic indications by which a deficiency and too large an excess of potassium cyanide in the bath, as well as an insufficient content of metal, may be recognized, have already been discussed, and it is here only necessary to refer to the quantitative determination of the separate constituents.

*Free potassium cyanide and the content of copper* are determined in the same manner as described under copper baths containing potassium cyanide. Hence only the *determination of zinc* has here to be considered. For making this determination, it is necessary to destroy the cyanide combinations, and entirely to remove the copper. For this purpose bring by means of the pipette 10 cubic centimeters of the brass bath into a porcelain dish, and proceed in the same manner as given on p. 277 for the determination of copper by electrolysis. Dissolve the evaporated residue in the dish in water, adding a few drops of pure hydrochloric acid. Then bring the solution into a capacious beaker, dilute with water to about 250 cubic centimeters, and heat to boiling. Now add about 10 cubic centimeters of pure dilute sulphuric acid (1 : 10) and, stirring constantly, mix with a solution of 2.5 grammes of crystallized sodium. Copper sulphide is separated under the escape of sulphurous acid. Cover the beaker with a watch glass, let it stand for 15 minutes, and then filter off the precipitate. Wash the filter thoroughly with sulphuretted hydrogen water, and evaporate the filtrate together with the wash waters to about 100 to 150 cubic centimeters. The solution contains all the zinc, and can be at once titrated (see below).

For the determination of zinc by electrolysis, heat the solution to boiling, mix it with solution of sodium carbonate in excess, and, after the precipitate of basic zinc carbonate has settled, filter it off. Dissolve the precipitate in the filter with pure dilute sulphuric acid, bring the filtrate together with the waters used for thoroughly washing the filter into a clean beaker, and neutralize accurately with sodium carbonate.

Now bring into the platinum dish, previously coppered, 5

grammes of potassium oxalate and 2 grammes of potassium sulphate dissolved in a small quantity of water, fill the platinum dish up to within 1 centimeter from the rim with distilled water, and electrolyze with a current-density of  $ND_{100} = 0.5$  ampère. The dull, bluish-white deposit of zinc is treated with water, then with alcohol and ether, dried in the exsiccator over sulphuric acid, and weighed. The determined weight of the zinc deposit multiplied by 100 gives the content of zinc in grammes per liter of brass bath.

*For the volumetric determination of the zinc*, about 100 to 150 cubic centimeters of the zinc solution resulting after the precipitation of the copper are used. The determination is based upon the principle that potassium ferrocyanide solution precipitates the zinc from the solution, and that complete precipitation is indicated by an excess of potassium ferrocyanide, yielding a brown coloration with uranium acetate. If now the content of the potassium ferrocyanide solution is known, the quantity of it used gives the content of zinc. It is best to use a solution which contains per liter 32.45 grammes of pure crystallized potassium ferrocyanide, every cubic centimeter of this solution corresponding to 0.01 gramme of zinc. Add, stirring constantly, from a burette potassium ferrocyanide solution to the zinc solution in a beaker until a drop of the fluid brought upon a strip of filtering paper previously saturated with uranium acetate solution and again dried just shows the commencement of a brown coloration.

Since 10 cubic centimeters of brass bath were used, the number of cubic centimeters of potassium ferrocyanide solution used gives the quantity of zinc in grammes per liter of brass bath. Suppose 16 cubic centimeters of solution have been used, this would correspond to 0.16 gramme zinc ( $0.01 \times 16$ ). Hence since 10 cubic centimeters of bath contain 0.16 gramme, the bath contains 16 grammes ( $0.16 \times 100$ ) of zinc per liter.

If now a deficiency of zinc in the bath has been determined, the initial content can be readily restored by an addition of pure potassium zinc cyanide, which contains 21 per cent. of



zinc. The quantity required is determined in the same manner as given under copper baths.

### 3. DEPOSITION OF BRONZE.

The electro-plating of metallic objects with bronze, *i. e.*, a copper-tin alloy, or an alloy of copper, tin, and zinc, is but seldom practiced, the bronze tone being in most cases imitated by a deposit of brass, with a somewhat larger content of copper.

For coating *wrought- and cast-iron* with bronze, Gountier recommends the following solution:—

Yellow prussiate of potash  $10\frac{1}{4}$  ozs., cuprous chloride  $5\frac{1}{4}$  ozs., stannous chloride (tin salt) 14 ozs., sodium hyposulphite 14 ozs., water 10 quarts.

According to Ruolz, a bronze bath is prepared as follows: Dissolve at  $122^{\circ}$  to  $140^{\circ}$  F., cyanide of copper 2.11 ozs., and oxide of tin 0.7 oz. in 10 quarts of potassium cyanide solution of  $4^{\circ}$  Bé. The solution is to be filtered.

Elsner prepares a bronze bath by dissolving 21 ozs. of blue vitriol in 10 quarts of water, and adding a solution of  $2\frac{1}{2}$  ozs. of chloride of tin in potash lye.

Salzède recommends the following bath, which is to be used at between  $86^{\circ}$  and  $95^{\circ}$  F.: Potassium cyanide  $3\frac{1}{2}$  ozs., carbonate of potash  $35\frac{1}{4}$  ozs., stannous chloride (tin salt) 0.42 oz., cuprous chloride  $\frac{1}{2}$  oz., water 10 quarts.

Weil and Newton claim to obtain beautiful bronze deposits from solutions of the double tartrate of copper and potash, and the double tartrate of the protoxide of tin and potash, with caustic potash, but fail to state the proportions.

The above formulæ are here given with all reserve, since experiments with them failed to give satisfactory results. With Gountier's, Ruolz's, and Elsner's baths no deposit was obtained, but only a strong evolution of hydrogen, while even with a strong current Salzède's bath did not yield a bronze deposit, but simply one of tin.

*The following method of preparing a bronze bath may be*

*recommended*: Prepare, each by itself, solutions of phosphate of copper and stannous chloride (tin salt) in sodium pyrophosphate. From a blue vitriol solution precipitate, with sodium phosphate, phosphate of copper, allow the latter to settle, and after pouring off the clear supernatant fluid bring it to solution by concentrated solution of sodium pyrophosphate. On the other hand, add to a saturated solution of sodium pyrophosphate solution of tin salt as long as the milky precipitate formed dissolves. Of these two metallic solutions, add to a solution of sodium pyrophosphate, which contains about  $1\frac{3}{4}$  ozs. of the salt to the quart, until the precipitate appears quickly and of the desired color. For anodes, use cast bronze plates, which dissolve well in the bath. Some sodium phosphate has from time to time to be added to the bath, and if the color becomes too light, solution of copper, and if too dark, solution of tin.

For *deposits of tombac* Hess's bath (formula VII., Deposition of Brass) with anodes of plate or sheet tombac can be recommended; 3 to 3.5 volts being the most suitable tension of the current for the decomposition of the bath.

For nickel bronze, see p. 247.

The execution of bronzing requires the same attention and manipulations as given for Deposition of Brass.

## CHAPTER IX.

### DEPOSITION OF SILVER.

*Properties of silver.*—Pure silver is the whitest of all known metals. It takes a fine polish, is softer and less tenacious than copper, but harder and more tenacious than gold. It is very malleable and ductile, and can be obtained in exceedingly thin leaves and fine wire. Its specific gravity is 10.48 to 10.5, according to whether it is cast or hammered. It melts at about  $1832^{\circ}$  F. It is unacted upon by the air, but in the atmosphere of towns it gradually becomes coated with a film of silver sulphide. It is rapidly dissolved by nitric acid, nitrogen dioxide being evolved. Hydrochloric acid has but little action upon it even at boiling heat; when heated with concentrated sulphuric acid it yields sulphur dioxide and silver sulphate.

Chlorine acts upon silver at the ordinary temperature. Silver has great affinity for sulphur, and readily fuses with it to silver sulphide. Sulphuretted hydrogen blackens silver, brown-black silver sulphide being formed (tarnishing of silver in rooms in which gas is burned). Such tarnishing is most readily removed by potassium cyanide solution.

Watery chromic acid converts silver into red silver chromate, and this conversion is made use of for the recognition of silvering. By touching silver or genuine silver-plating with a drop of a solution obtained by dissolving potassium bichromate in nitric acid of 1.2 specific gravity, a red stain is formed.

Electro-plating with silver was, of all electro-metallurgical processes, the first which was carried on on a large scale, and the figures given below are an indication of the dimensions it has reached. Bouilhet stated before the Electrical Congress,

that in the establishment of Christofle & Co., of Paris, more than 13,200 lbs. of silver are annually consumed for plating purposes. Since 1842, when their business was established, up to 1885, 371,800 lbs. of silver had been used in electro-plating. It may be supposed that other large celebrated establishments use at least the same amount, and it may safely be said that the quantity of silver consumed annually in Europe and America for plating purposes amounts to from 330,000 to 352,000 lbs.

*Silver baths.*—The longer an electro-plating process has been carried on, the greater, as a rule, the number of existing formulæ for baths will be; but silver baths are an exception to this rule. If it is taken into consideration that silver-plating has been practically carried on for about sixty years, the number of formulæ might be expected to be at least equal to those for nickel-plating, which is of much more recent origin. Such, however, is not the case, and chiefly for the reason that the attempts to improve the silver baths, which were made either with a view to banish the poisonous potassium cyanide from the silver-plating industry, or otherwise to advance the plating process, could absolutely show no better results than the baths used by the first silver-platers. However, that attempts to make such improvements have not been entirely abandoned, is shown by Zinin's proposition to substitute solution of silver iodide in potassium iodide for a solution containing potassium cyanide. Experiments, however, have shown that the results with this process, like with many other modern methods, are not equal to those obtained with the approved baths which have stood the test of time. Hence, only formulæ for the most approved baths will here be given.

*Silver bath for a heavy deposit of silver* (plating by weight).  
—I. 98 per cent. potassium cyanide 14 ozs., fine silver as silver chloride  $8\frac{3}{4}$  ozs., distilled water 10 quarts.

Ia. 98 per cent. potassium cyanide  $8\frac{3}{4}$  ozs., fine silver as silver cyanide  $8\frac{3}{4}$  ozs., distilled water 10 quarts.

Before describing the preparation of the bath a few words may



be said in regard to the old dispute whether it is preferable to use silver cyanide or silver chloride. Without touching upon all the arguments advanced, it may be asserted, by reason of conscientious comparative experiments, that the results are the same, and that the life of the bath is also the same, whether one or the other salt has been used in its original preparation. From a theoretical standpoint, silver cyanide must be given the preference; but as the disadvantages in respect to the life of the bath ascribed by some to silver chloride do not exist, it might be advisable for those who prepare their own baths to use silver chloride.

*Preparation of bath I. with silver chloride.*—Dissolve 14 ozs. of chemically pure nitrate of silver, best the crystallized, and not the fused, article, in 5 quarts of water, and add to the solution pure hydrochloric acid, or common salt solution, with vigorous stirring or shaking, until a sample of the fluid filtered through a paper filter forms no longer a white caseous precipitate of silver chloride when compounded with a drop of hydrochloric acid. These, as well as the succeeding operations, until the silver chloride is ready, have to be performed in a darkened room, as silver chloride is partially decomposed by light. Now separate the precipitate of silver chloride from the solution by filtering, using best a large bag of close felt, and wash the precipitate in the felt bag with fresh water. Continue the washing until blue litmus-paper is no longer reddened by the wash-water, if hydrochloric acid was used for precipitating, or, if common salt solution was used, until a small quantity of the wash-water, on being mixed with a drop of lunar caustic solution, produces only a slight milky turbidity and no precipitate. Now bring the washed silver chloride in portions from the felt bag into a porcelain mortar, rub it with water to a thin paste, and pour the latter into the potassium cyanide solution consisting of 14 ozs. of 98 per cent. potassium cyanide in 5 quarts of water, in which, by vigorous stirring, the silver chloride gradually dissolves. All the precipitated silver chloride having been brought into solution, dilute with water to 10 quarts of fluid,

and boil the bath, if possible, for an hour, replacing the water lost by evaporation. A small quantity of black sediment containing silver thereby separates, from which the colorless fluid is filtered off. The sediment is added to the silver residues, and is worked together with them for the recovery of the silver by one of the methods to be described later on.

*Preparation of bath Ia. with silver cyanide.*—Dissolve 14 ounces of chemically pure crystallized nitrate of silver in 5 quarts of water, and precipitate the silver with prussic acid, adding the latter until no more precipitate is produced by the addition of a few drops of prussic acid to a filtered sample of the fluid. Now filter, wash, and proceed for the rest exactly as stated for the bath with silver chloride, except that only  $8\frac{3}{4}$  ounces of potassium cyanide are taken for dissolving the silver cyanide. In working with prussic acid avoid inhaling the vapor which escapes from the liquid prussic acid, especially in the warm season of the year; and be careful the acid does not come in contact with cuts on the hands. It is one of the most rapidly-acting poisons.

Silver cyanide may also be prepared as follows: Dissolve 14 ounces of chemically pure crystallized nitrate of silver in 5 quarts of water, and add moderately concentrated potassium cyanide solution until no more precipitate is formed, avoiding, however, an excess of the precipitating agent, as it would again dissolve a portion of the silver cyanide. The precipitated silver cyanide is filtered off, washed and dissolved in potassium cyanide, as above described.

The preparation of the silver bath according to the above formulæ is more conveniently effected by using pure crystallized potassium silver cyanide in the following proportions:

*Ib.* 98 per cent. potassium cyanide,  $6\frac{1}{3}$  to 7 ozs.; crystallized potassium silver cyanide,  $17\frac{1}{2}$  ozs.; distilled water, 10 quarts. The salts are simply dissolved in the cold water.

The baths prepared according to formulæ I, Ia or Ib serve chiefly for the production of a heavy deposit upon German silver articles, especially table and other household utensils.

Of course, they may also be used for plating other metals by weight.

*Silver bath for ordinary electro-silvering.*—II. 98 per cent. potassium cyanide,  $6\frac{1}{4}$  to 7 ounces; fine silver (as silver nitrate or chloride),  $3\frac{1}{2}$  ounces; distilled water, 10 quarts.

To prepare the bath dissolve  $5\frac{1}{2}$  ounces of chemically pure crystallized nitrate of silver in 5 quarts of distilled water; in the other 5 quarts of water dissolve the potassium cyanide, and mix both solutions. Or, if chloride of silver is to be used, precipitate the solution of  $3\frac{1}{2}$  ounces of the silver salt in the same manner as given for formula I.; wash the precipitated chloride of silver, and dissolve it in the potassium cyanide solution.

*Ia.* 98 per cent. potassium cyanide  $1\frac{2}{5}$  ozs., crystallized potassium silver cyanide 7 ozs., distilled water 10 quarts.

Dissolve the salts in the cold water.

Tanks of stone-ware or enameled iron are only to be used for silver baths.

*Treatment of the silver baths.*—*Silver anodes.* Frequently the error is committed of adding too much potassium cyanide to the bath. A certain excess of it must be present, and, in the formulæ given, this has been taken into consideration. For dissolving the silver cyanide prepared from 14 ounces of nitrate of silver, as given in formula Ia, only about  $5\frac{1}{2}$  ounces of potassium cyanide are required, and the consequence of working with such a bath devoid of all excess would be that, on the one hand, the bath would offer considerable resistance to the current, and, on the other, that the deposit would not be uniform and homogeneous. Hence with the use of a medium strong current about 30 to 35 per cent. more potassium cyanide than fine silver is taken. In working with a stronger current this excess would, however, be too large, and the deposit would not adhere properly and would peel off in scratch-brushing. And again, with a weak current the baths can, without disadvantage, stand a larger excess. As a rule, however, the proportion between fine silver and potassium cyanide in the above formulæ may be considered as normal, and the current-strength

will have to be regulated so that a deposit of fine structure, which adheres firmly, is formed. The most suitable current-strength per  $15\frac{1}{2}$  square inches of surface is 0.25 to 0.15 ampère, and 0.5 to 0.75 volt tension; the tension of a Daniell element being more than sufficient for the decomposition of the silver bath. On account of the silver bath requiring a current of slight electro-motive force the Smee element, which yields 0.48 volt, is much liked for silver-plating in this country and in England. The Bunsen element may, however, also be used if the surface to be plated is made to correspond with the energy of such an element; or if a resistance board is placed in the circuit, which is advisable in all cases. On account of the slight electro-motive force required in silver-plating larger surfaces of objects, the elements are not to be coupled one after the other for electro-motive force, but alongside one another for quantity. In no case must an evolution of hydrogen be perceptible on the articles, and the current must be more weakened the larger the excess of potassium cyanide in the bath.

Whether too much, or not enough, potassium cyanide is present in the bath is indicated by the appearance of the plated objects and the properties of the deposit, as well as by the behavior of the anodes in the bath during and after silvering.

It may be accepted, as a rule, that with a moderate current the object must, in the course of 10 to 15 minutes, be coated with a thin, dead white film of silver. If this be not the case, and the film of silver shows a meager bluish-white tone, potassium cyanide is wanting. However, if, on the other hand, the dead white deposit forms within 2 or 3 minutes, and shows a crystalline structure, or a dark tone playing into gray-black, the content of potassium cyanide in the bath is too large, provided the current is not excessively strong. If copper and brass become coated with silver without the co-operation of the current, the bath contains also too much potassium cyanide.

In silver-plating, even if the objects are to be thinly coated, insoluble platinum anodes should never be used, but only



anodes of fine silver, which are capable of maintaining the content of silver in the bath quite constant. From the behavior and appearance of the anodes, a conclusion may also be drawn as to whether the content of potassium cyanide in the bath is too large or too small. If the anodes remain silver-white during plating, it is a sure sign that the bath contains more potassium cyanide than is necessary and desirable; but, if they turn gray or blackish, and retain this color after plating, when no current is introduced into the bath for a quarter of an hour or more, potassium cyanide is wanting. On the other hand, the correct content of potassium cyanide is present when the anodes acquire during the plating process a gray tone, which, after the interruption of the current, gradually changes back to a pure white.

The proposition to use steel plates in place of silver anodes cannot be approved, and as regards such anodes the reader is referred to what is said under "Deposition of Gold."

If it is shown by the process of silvering itself, or by the appearance of the articles or of the anodes, that potassium cyanide is wanting in the bath, it should be immediately added, though never more than 30 to  $37\frac{1}{2}$  grains per quart of bath at one time, so as to avoid going to the other extreme. Too large a content of potassium cyanide is remedied by adding to the bath, stirring constantly, a small quantity of cyanide or chloride of silver rubbed with water to a thinly-fluid paste, whereby the excess is rendered harmless in consequence of the formation of the double salt of silver and potassium cyanide. Instead of such addition, the current may, however, be used for correcting the excess. For this purpose suspend as many silver anodes as possible to the anode-rods, but only a single anode as an object to the object-rod, and allow the current to pass for a few hours through the bath, whereby the excess of potassium cyanide is removed and rendered harmless by the dissolving silver.

The bath can be kept quite constant by silver anodes, provided potassium cyanide be regularly added at certain inter-

vals, and the anode-surface is equal to that of the objects to be plated. But since, on account of the expense, a relatively small anode-surface is frequently used, the content of silver in a bath continuously worked will finally become lower, and augmentation, by the addition of silver, will be required. The manner of effecting this augmentation depends on whether the baths are used for plating by weight or for lighter silvering, or whether the baths are worked, without stopping, from morning till evening. For replacing the deficiency in baths prepared according to formulæ I and Ia, it is advisable to use exclusively solution of silver cyanide in potassium cyanide, or of crystallized potassium silver cyanide in water.

It has previously been mentioned that with proper treatment baths made with chloride of silver have the same duration of life as those prepared with silver cyanide. The chief feature of such proper treatment is not to use chloride of silver dissolved in potassium cyanide for augmenting the content of silver, but to employ silver cyanide instead, since by the use of the former the bath thickens in consequence of the potassium chloride which is simultaneously introduced; and would offer greater resistance to the current. The fear expressed by some authors that a crystalline separation of potassium chloride, and the consequent formation of a deposit full of holes might take place, is, however, not well founded, since potassium chloride is one of the most soluble salts, and shows but little tendency to separate in crystals from aqueous solutions. The gradual thickening above referred to is, however, a disadvantage, which shows itself by the deposit being less homogeneous, and for this reason it is advisable, when plating by weight, to use silver cyanide in place of the chloride for strengthening the silver bath.

A gradual thickening of the bath may also take place if potassium cyanide containing potash is used instead of the preparation free from potash, and of 98 to 99 per cent. purity. Even pure fused potassium cyanide produces a thickening of the bath, which, however, progresses very slowly. This thickening

is due to a portion of the excess of potassium cyanide being converted by the action of the air into potassium carbonate. The latter thus formed must from time to time be neutralized, which is generally done with prussic acid, the potassium carbonate being thereby converted into potassium cyanide. Instead of prussic acid, calcium cyanide, or barium cyanide, may be added as long as a precipitate of calcium carbonate or barium carbonate is formed, the clear solution being separated from the precipitate by filtering.

For augmenting the content of silver in baths prepared according to formula II., solution of nitrate or of chloride of silver in potassium cyanide may unhesitatingly be used, since the thickening proceeds more slowly on account of the smaller content of salt in the bath, and because a cheaper bath can be more readily renewed without the sacrifice of money than one for heavy deposits. The recovery of silver from old baths is effected by one of the methods given later on.

Since, as mentioned above, the proportion of excess of potassium cyanide to the content of silver undergoes changes according to the proportion of the object-surface to the anode-surface, the temperature of the bath, etc., it becomes necessary to add one or the other in order to maintain the proper proportions and the effective working of the bath.

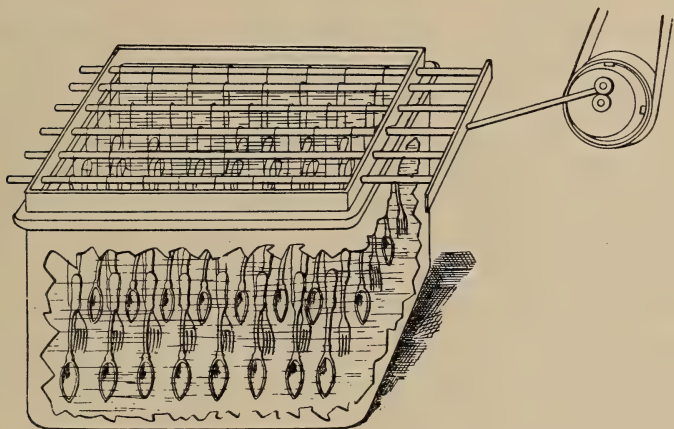
To determine whether the bath contains silver and excess of potassium cyanide in proper proportions, the following methods may be used: Dissolve 1 gramme (15.43 grains) of chemically pure crystallized nitrate of silver in 20 grammes (0.7 oz.) of water and gradually add this solution, whilst constantly stirring with a glass rod, to 100 grammes (3.52 ozs.) of the silver bath in a beaker, as long as the precipitate of silver cyanide formed dissolves by itself. If, after adding the entire quantity of silver solution, the precipitate dissolves rapidly, too large an excess of potassium cyanide is present in the bath; and *vice versa*, if the precipitate does not completely dissolve, after stirring, potassium cyanide is wanting.

The quantitative determination of content of potassium cyan-

ide and of silver will be described later on under "Examination of Silver Baths."

In silver-plating, *constant agitation* of the strata of fluid is of decided advantage, streaks and blooms being otherwise readily formed upon the plated objects. To keep the articles in gentle motion while in the bath, one method is to connect the suspending rods to a frame of iron having four wheels, about 3 inches in diameter, connected to it, which slowly travel to and fro to the extent of 3 or 4 inches upon inclined rails attached to the upper edges of the tank, the motion, which is both horizontal and vertical, being given by means of an eccentric wheel

FIG. 129.



driven by steam power. By another arrangement, the frame supporting the articles does not rest upon the tank, but is suspended above the bath, and receives a slow swinging motion from a small eccentric or its equivalent. In the Elkington establishment at Birmingham the following arrangement is in use: All the suspending rods of the bath rest upon a copper mounting, which, by each revolution of an eccentric wheel, is lifted about  $\frac{3}{4}$  inch, and then returned to its position. The copper mounting is connected to the main negative wire of the dynamo-machine by a copper cable. The same object may



also be attained by giving the articles a horizontal, instead of a vertical motion, as shown in Fig. 129, in which the motion is produced by an eccentric wheel on the side.

With equal, if not better, success the mechanically moved stirring apparatus which will be described under "Copper Galvano-plasty," may be used. In this apparatus several glass rods movable around a pivot keep the bath in constant motion. Where such a stirring apparatus cannot be conveniently arranged, the motion of the bath may be produced by introducing, by means of a pump, air on the bottom of the tank.

A singular phenomenon in regard to silver baths, which has not yet been explained, may here be mentioned. A small addition of certain, and especially of organic, substances, which, however, must not be made suddenly or in too large quantities, produces a fuller and better-adhering deposit of greater lustre than can be produced in fresh baths. Elkington observed that an addition of a few drops of bisulphide of carbon to the bath made the silvering more lustrous, while others claim to have used with success solutions of iodine in chloroform, of gutta-percha in chloroform, as well as heavy hydrocarbons, tar, oils, etc.

Some preparations which have been recommended for this "bright" plating may here be given. Bring 6 ozs. of bisulphide of carbon into a stoppered bottle and add 1 gallon of the usual plating solution. Shake the mixture thoroughly and then set it aside for 24 hours. Add 2 ozs. of the resulting solution to every 20 gallons of ordinary plating solution in the vat, and stir thoroughly. This proportion must be added every day, but where the mixture has been used every day, less than this may be used at a time. This proportion is claimed to give a bright deposit, but by adding a larger amount a dead surface may be obtained, very different from the ordinary dead surface.

Another method of preparing a solution for bright-plating is as follows: Put 1 quart of ordinary silver-plating solution into a large stoppered bottle. Now add 1 pint of strong solution of cyanide, and shake well; 4 ozs. of bisulphide of carbon are

then added, as also 2 or 3 ozs. of liquid ammonia, and the bottle again well shaken, this operation being repeated every two or three hours. The solution is then set aside for about 24 hours, when it will be ready for use. About 2 ozs. of the clear liquid may be added to every 20 gallons of plating solution, and well mixed by stirring. A small quantity of the brightening solution may be added to the bath every day, and the liquid then gently stirred. In course of time the bisulphide solution acquires a black color, to modify which a quantity of strong cyanide solution, equal to the brightening liquor which has been removed from the bottle, should be added each time. In adding the bisulphide solution to the plating bath, an excess must be avoided, otherwise the latter will be spoilt. Small doses repeated at intervals is the safer procedure, and less risky than the application of larger quantities, which may ruin the bath.

A very simple way to prepare the brightening solution is to put 2 or 3 ozs. of bisulphide of carbon into a bottle which holds rather more than half a gallon. Add to this about 3 pints of old silver solution and shake the bottle well for a minute or so. Then nearly fill the bottle with a strong solution of cyanide, shake well as before, and set aside for at least 24 hours. Add about 2 ozs. (not more) of the brightening liquor, without shaking the bottle, to each 20 gallons of solution in the plating vat. Even at the risk of a little loss from evaporation, it is best to add the brightening liquor to the bath the last thing in the evening, when the solution should be well stirred so as to thoroughly diffuse the added liquor. The night's repose will leave the bath in good working order for the following morning.

A silver bath, as shown by experience, becomes without doubt better in the degree as it takes up small quantities of organic substances from the air and from dust; but numerous experiments have failed to confirm Elkington's observation that the formation of the deposit or its appearance is essentially influenced by the addition of bisulphide of carbon or any of the

above-mentioned solutions of organic origin either in very small or considerable quantities. Many baths have been entirely spoiled by an attempt to change them into bright working baths by the addition of such ingredients, and hence it is best to leave such experiments alone. It may, however, be stated that by the addition of a few drops of spirits of sal ammoniac, fresh silver baths accommodate themselves more rapidly to regular performance.

After plating, the objects frequently show, instead of a pure white, a yellow tone, or they become yellow in the air, which is ascribed to the formation of basic silver salts in the deposit. To overcome this evil it has been proposed to allow the objects to remain in the bath for a few minutes after interrupting the current, whereby the basic salts are dissolved by the potassium cyanide of the bath; or the same object is attained by inverting the electrodes for a few seconds, after plating, thus transforming the articles into anodes. The electric current carries away the basic salt of silver in preference to the metal. This operation should, of course, not be prolonged, otherwise the silver will be entirely removed from the objects, and will be deposited on the anodes. For the same purpose some electroplaters hold in readiness a warm solution of potassium cyanide, in which they immerse the plated articles for half a minute.

It has been proposed to add to the silver baths a solution of nickelous cyanide in potassium cyanide in order to obtain a deposit of a silver-nickel alloy, which is claimed to be distinguished by its greater hardness and the property of not turning so readily dark. Numerous experiments with solutions of cyanide of silver and nickelous cyanide in potassium cyanide in all possible proportions, and under various tensions of current and subsequent analysis of the deposits obtained, showed, however, only inconsiderable traces of nickel in the silver deposit, which had but a very slight influence upon the hardness and durability of the silver.

The London Metallurgical Co. endeavors to attain greater hardness and power of resistance of the silver by adding zinc

cyanide or cadmium cyanide, and has given to this process the name of *arcas* silver-plating. According to the patent an addition of 20 to 30 per cent. of zinc or cadmium to the silver prevents the tarnishing of the plating, and besides the deposit is claimed to be lustrous and hard. For *arcas* silver-plating the appropriate quantity of zinc or cadmium, or a mixture of both metals, is converted into potassium-zinc cyanide or potassium-cadmium cyanide, and this solution is mixed with a corresponding quantity of solution of potassium silver cyanide, with a small excess of potassium cyanide. Sheets of a silver-zinc or a silver-cadmium alloy are used as anodes.

Some English electro-platers claim that for many articles, especially bicycles, *arcas* silver-plating may be substituted for nickeling.

The following experiments may serve as an illustration regarding the value of this process as a substitute for silver-plating instruments and articles of luxury:—

A bath was prepared which contained per quart 231½ troy grains of fine silver and 77 troy grains cadmium in the form of cyanide double salts with a small excess of potassium cyanide. The most suitable tension of current for the decomposition of a pure potassium-cadmium cyanide solution which contained per quart 154 troy grains of cadmium with the same excess of potassium cyanide as the above-mentioned mixture, was found to be 2 volts.

In electrolyzing the cadmium-silver bath with 0.75 volt, a uniform silver-white deposit similar to that of pure silver was at first formed. However, after two hours the deeper places of the objects suspended in the bath showed crystalline excrescences which felt sandy and could be rubbed off with the fingers. After scratch-brushing the articles and again suspending them in the bath, these sandy non-adhering metallic deposits were rapidly reformed. An analysis of the deposit separated from the articles showed 96.4 per cent. silver, and 3.2 per cent. cadmium. This deposit could, without difficulty, be polished with the steel like a pure silver deposit, and hence



its hardness would not seem greater than that of pure silver. Its capability of resisting hydrogen sulphide as compared with that of pure silver was scarcely greater.

In another experiment electrolysis was effected with 1.25 volts. The deposit showed from the start a coarser structure, and the formation of the sandy non-adhering deposit took place much more rapidly. But, on the other hand, the hardness of the separated coherent metal was greater than that of pure silver, and also its power of resisting hydrogen sulphide. An analysis of the deposit showed 92.1 per cent. silver and 7.8 per cent. cadmium. In both cases the deposit was dull like that of pure silver.

With a greater tension of current the quantity of cadmium in the deposit increased, and the hardness of the latter became correspondingly greater. However, these deposits could not be considered serviceable for the above-mentioned purpose, because they could not be made of sufficient thickness as required for solid silver-plating of forks and spoons.

*Execution of silver-plating—A. Silver-plating by weight.*—Current-density 0.25 to 0.35 ampère per square decimeter (15.5 square inches.) Copper, brass, and all other copper alloys may be directly plated after amalgamating (quicking), whilst iron, steel, nickel, zinc, tin, lead, and Britannia are first coppered or brassed, and then amalgamated.

The mechanical and chemical preparation of the objects for the silver-plating process is the same as described on pages 161 and 169. To obtain well-adhering deposits great care must be exercised in freeing the objects from grease and in pickling. As a rule, objects to be silver-plated are ground and polished. However, polishing must not be carried too far, since the deposit of silver does not adhere well to highly-polished surfaces; and in case such highly-polished objects are to be silvered it is best to deprive them of their smoothness by rubbing with pumice powder, emery, etc., or by pickling.

The treatment of copper and its alloys, German silver and brass, which have chiefly to be considered in plating by weight, is, therefore, as follows:—

1. *Freeing from grease* by hot potash or soda lye (1 part of caustic alkali to 8 or 10 parts of water), or by brushing with the lime-paste mentioned on page 170.

2. *Pickling* in a mixture of 1 part, by weight, of sulphuric acid of 66° Bé. and 10 of water. This pickling is only required for rough surfaces of castings, ground articles being immediately after freeing from grease treated according to 3.

3. *Rubbing* with a piece of cloth dipped in fine pumice powder or emery, after which the powder is to be removed by washing.

4. *Pickling* in the preliminary pickle, rinsing in hot water, and quickly drawing through the bright dipping bath (page 163), and again thoroughly rinsing in several waters.

5. *Amalgamating (quicking)* by immersion in a solution of mercury, called the quicking solution. This consists of a solution of 0.35 ounce of nitrate of mercury in 1 quart of water, to which, while constantly stirring, pure nitric acid in small portions is added until a clear fluid results. A weak solution of potassium mercury cyanide in water is, however, to be preferred, because the acid-quicking solution mentioned above makes the metals brittle. A quicking solution for silver-plating by weight consists of: Potassium mercury cyanide, 14 drachms to 1 oz.; 99 per cent. potassium cyanide, 14 drachms; water, 1 quart. Care must be taken to bring the quicked objects into the bath as rapidly as possible, otherwise thin objects are liable to become brittle. The amalgam formed upon the surface penetrates to the interior of thin sheets if this action is not prevented by an immediate deposition of silver and the formation of silver amalgam. In the quicking solution the objects remain only long enough to acquire a uniform white coating, when—

6. They are rinsed in clean water, and gone over with a soft brush in case the quicking shows a gray, instead of a white tone.

The articles are now brought into the silver bath, and secured to the object rods by slinging wires of pure copper or,

still better, of pure silver. The latter have the advantage that when by reason of a deposit of considerable thickness having been formed upon them, they have become useless for suspending the articles, they can be directly converted into silver nitrate by dissolving in nitric acid, and used for the preparation of fresh baths, or for strengthening old baths.

When certain objects, for instance, forks and spoons are to

FIG. 130.



be plated, copper wires may be bent in the manner shown in Fig. 130. To prevent the deposition of silver upon the portions of the wire which do not serve for the purpose of contact, they are coated with fused ebonite mass or gutta percha, only the loop in which the fork or spoon is hung and the upper end for suspending to the object-rod being left free. Silver wires are also better for this purpose.

Introduce into the bath at first a somewhat more powerful current, so that the first deposit of silver takes place quite rapidly, and after 3 minutes regulate the current so that in 10 to 15 minutes the objects are coated with a thin, dull film of silver. At this stage take them from the bath, and after seeing that all portions are uniformly coated, scratch-brush them with a brass brush, which should, however, not be too fine. In doing this the deposit must not raise up. If at this stage the objects stand thorough scratch brushing, raising of the deposit in burnishing later on need not be feared.

Any places which show no deposit are vigorously scratch-brushed with the use of pulverized tartar, then again carefully cleansed by brushing with lime-paste to remove any impurities due to touching with the hands, pickled by dipping in potassium cyanide solution, rinsed off again, quicked, and after careful rinsing returned to the bath. Special care must be had not to contaminate the bath with quicking solution, as this would soon spoil it.

The objects now remain in the bath until the deposit has acquired a weight corresponding to the desired thickness. Knives,

forks, and spoons receive a deposit of 2.11 to 3.52 ozs. of silver per dozen, such deposit being produced with elements in 10 to 14 hours, and with a dynamo in 4 to 5 hours. According to Dr. William H. Wahl, the amount of silver deposited upon the several grades of plated table-ware manufactured by the William Rogers Manufacturing Co., of Hartford, Conn., is as follows:

Per gross.	Extra plate.	Double plate.	Triple plate.
Teaspoons.....	48 dwts.	4 ozs.	6 ozs.
Desertspoons and forks.....	72 "	6 "	9 "
Tablespoons and med. forks...	96 "	8 "	12 "

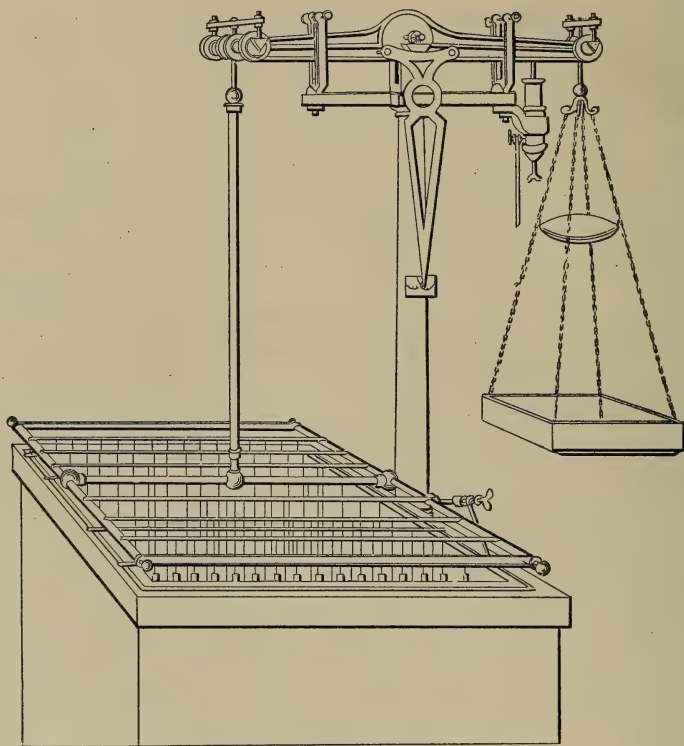
In order to control the weight of the deposit proceed as follows: After having removed one of the pans of a sensitive beam balance, substitute for it a brass rod, which keeps the other pan in equilibrium. Under this rod place a vessel filled with pure water and of sufficient diameter and depth to allow of the article suspended to the rod dipping entirely into the water without touching the sides of the vessel. Suppose now that several dozen spoons of the same size and shape are at the same time to be provided with a deposit of a determined weight, it suffices to control the weight of the deposit of a single spoon, and when this has acquired the necessary deposit all the other spoons will also be coated with a deposit of silver of the same thickness as the test spoon. After quicking and carefully rinsing the spoons, one of them is suspended to the brass rod of the balance so that it dips entirely under water. The equilibrium is then re-established by placing lead shot upon the pan of the scale, and adding the weight corresponding to the deposit the spoon is to receive. Now bring the weighed spoon together with the rest into the bath, and proceed with the silvering process in the ordinary manner. After some time the weighed spoon is taken from the bath, rinsed in water, and hung to the brass rod of the scale. If it does not restore the equilibrium of the latter, it is returned to the bath, after some time again weighed, and so on until its weight corresponds to that of the



lead shot and weight placed in the pan of the scale, when it is assumed that the balance of the articles have also received their proper quantity and that the operation is complete.

A more complete weighing apparatus is the plating balance first used by Brandely and later on improved by Roseleur. The apparatus, which is shown in Fig. 131, is designed for

FIG. 131.

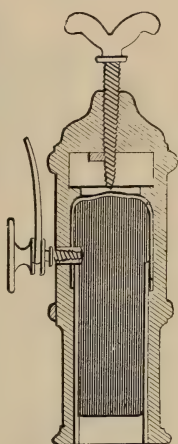


obtaining deposits of silver "without supervision and with constant accuracy, and which spontaneously breaks the current when the operation is terminated." It is manufactured in various sizes, suitable for small or large operations.

It consists of: 1. A wooden vat, the upper edge of which carries a brass winding-rod having a binding screw at one end

to receive the positive conducting wire of the battery. From this rod the anodes are suspended, which are entirely immersed in the solution, and communicate with brass cross-rods by means of platinum wire hooks. These cross-rods are flattened at their ends so that they may not roll, and at the same time have a better contact with the "winding-rod." 2. A cast-iron column screwed at its base to the side of the vat, and which carries near the top two projecting arms of cast-iron, the extremities of which are vertical and forked, and may be opened or closed by iron clamps. These forks are intended for sustaining the beam and preventing the knives from leaving their bearings under the influence of too violent oscillations. In the middle of the two arms are two wedge-shaped recesses of polished steel to receive the knife edges of the beam. One of the arms of the column carries at its end a horizontal ring of iron in which is fixed a heavy glass tube supporting a cup of polished iron which is insulated from the column (Fig. 132).

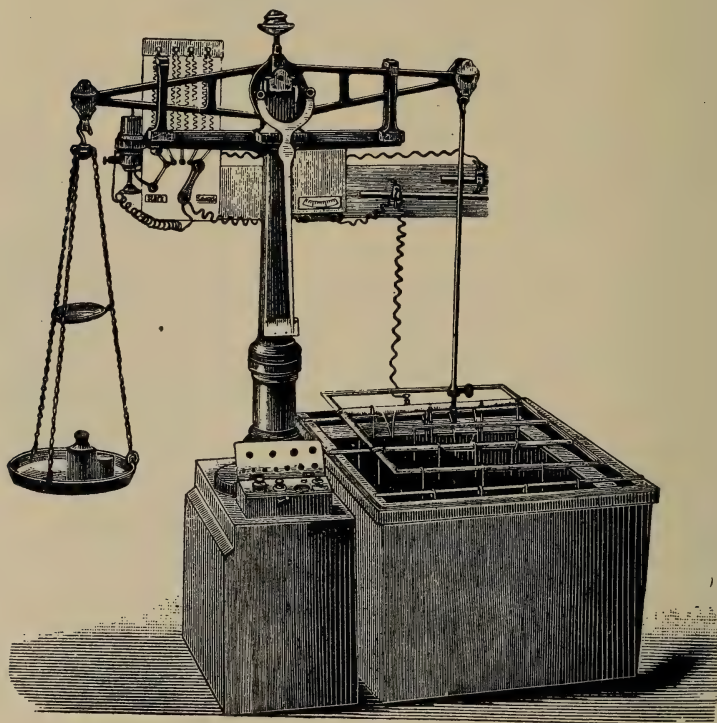
FIG. 132.



This cup has at its lower part a small pocket of lamb-skin or of India rubber, which by means of a screw beneath may be raised or lowered. This flexible bottom allows the operator to lower or raise at will the level of the mercury introduced afterwards into the iron cup. Another lateral screw permits connection to be made with the negative electrode. 3. A cast-iron beam carrying in the middle two sharp knife-edges of the best steel hardened and polished. At each extremity there are two parallel bearings of steel separated by a notch, and intended for the knife-edges of the scale-pan that receives the weights, and those of the frame supporting the articles to be plated. One of the arms of the beam is provided with a stout platinum wire, placed immediately above and in the centre of the cup of mercury. According as the beam inclines one way or the other, this wire

plays in or out of the cup. 4. A scale-pan for weights, with two knife-edges of cast-steel, which is attached to four chains supporting a wooden pan for the reception of weights. A smaller pan above is intended for the weights corresponding to that of the silver to be deposited. 5. The frame for supporting the articles to be plated, which is also suspended from two steel knife-edges, and the rod of which is formed of a stout

FIG. 133.



brass tube attached below to the brass frame proper, which last is equal in dimensions to the opening of the vat, and supports the rods to which the articles are suspended.

Fig. 133 shows a Roseleur plating balance, together with the resistance board, voltmeter, and silver bath; and will be understood without further explanation.

For calculating the weight of the deposit from the density of current, see "Chemical and Electric Equivalents," in the Appendix.

When the articles have received a deposit of the required weight, they are treated for the prevention of subsequent yellowing according to one of the methods given on p. 306, then scratch-brushed with the use of decoctions of soap-root, plunged in hot water and dried in sawdust.

Articles which are to retain the beautiful crystalline dead white with which they come from the bath are, without touching them with the fingers or knocking them against the sides of the vessel, plunged into very hot clean water, and then suspended free to dry. Immediately after drying, they are to be provided with a thin coat of kristalline or zapon to protect the dead white coating, which readily turns yellow, and, moreover, is very sensitive.

The silvered articles having been scratch-brushed, must finally be polished, which may be effected upon a fine felt wheel with the use of rouge, but imparting high lustre by burnishing is to be preferred, the deposit being first treated with the steel burnisher, and then with the stone burnisher, as explained on p. 156.

In some establishments in which plated table-ware in large quantity is turned out, ingeniously devised burnishing machines driven by power are in use, by which much of the manual labor is spared. The knife, spoon, etc., each supported by its tips in a suitable holder, are very slowly rotated, while the burnishing tool moves quickly over the surface, performing the work rapidly and satisfactorily.

When burnishing is completed, the surface is wiped off longitudinally with an old, soft calico rag. Sawdust, hard cloth, and tissue paper produce streaks.

B. *Ordinary silver-plating*.—Objects which are to receive a deposit of less thickness, have to undergo exactly the same operations described under plating by weight, the only difference being that for quickening a weaker solution (15 to 31 grains



of nitrate of mercury to 1 quart of water), or very dilute solution of potassium mercury cyanide (77 grains of potassium mercury cyanide and 77 grains of potassium cyanide to 1 quart of water) is used, and that the objects remain a shorter time in the bath. As previously mentioned, iron, steel, zinc and tin should first be coppered or brassed. However, tin and Britannia may also be directly plated, but the bath must be rich in silver and contain a large excess of potassium cyanide. Further, the current should be so strong that the articles acquire a blue-gray color. They are then suspended in the silver bath of normal composition, and plating is finished with a normal current.

The same process is also suitable for plating articles of German silver rich in nickel. In polishing such articles it is frequently observed that the deposit rises, but by plating in the above-mentioned preparatory bath, and finishing in the normal bath, the deposit will very well bear polishing with the steel.

For silver-plating *Britannia ware* and *articles of tin*, Gore recommends the following process: Boil the articles in caustic potash solution, scratch-brush them, and plate them preparatively with a strong current and the use of large anode-surfaces in a hot silver bath (194° F.), and then finish deposition to the desired thickness in the ordinary cold silver bath.

According to an Australian patent, the following process is claimed to yield good results in *directly silver plating iron and steel*. The article to be plated having first been dipped in hot dilute hydrochloric acid, is brought into solution of mercury nitrate, and then connected with the zinc pole of a Bunsen element. It becomes quickly coated with a layer of mercury, when it is taken out, washed and brought into an ordinary silver bath. When covered with a layer of silver of sufficient thickness, it is heated to 572° F., the mercury evaporating at this temperature. It is claimed that silver deposited in this manner adheres more firmly than by any other process, but it is doubtful whether for solid silver-plating this method can replace previous coppering.

According to Dr. William H. Wahl, in the United States the

practice of previous coppering is not adopted either with Britannia metal or steel. The practice of different establishments in cleansing their work differs somewhat, but all aim at the same results, viz., to secure a smooth adhering coating of metal upon an inferior base.

The practice of the Meriden Britannia Co.'s works at Meriden, Conn., as observed by Dr. William H. Wahl, is substantially as follows:

*With Britannia or "white metal."* The article is first cleansed of all grease by immersion in boiling alkali; then into dilute hydrochloric acid; then into a "striking" solution, viz., a weak cyanide of silver solution with a large proportion of free cyanide of potassium, and a large silver anode operated with a very strong electric current. The purpose of immersion in this solution is to effect an instantaneous deposit of silver on the metal, to better insure a perfect coating in the silver bath proper. The articles remain in the "striking" solution for a few seconds only, as its action, owing to the large proportion of free cyanide it contains, is very prompt, and as soon as they have received a thin coating, which takes place almost immediately, they are removed to the electro-plating bath, where they remain until they have received the proper coating of silver. In many cases, especially with articles of considerable size, cleansing in boiling alkali must be supplemented by scratch-brushing, in which case the acid dip may be dispensed with, and the article, after thorough rinsing and dipping in alkali to remove finger-marks, is immersed at once in the "striking" solution.

*German silver or nickel articles* are first cleansed in boiling alkali, washed, then dipped in a mixture of two-thirds sulphuric acid and one-third nitric acid, then into quicking solution, then into the "striking" solution, and from this into the plating bath.

*Steel* articles are cleansed in boiling alkali, rinsed, dipped in hydrochloric acid, then in the "striking" solution, and from this into the plating bath. In case the articles require scouring, the acid dip is dispensed with. For *steel* two "striking" solu-

tions are used, one somewhat richer in silver than the other, the weaker solution being used first.

With the William Rogers Manufacturing Co., Hartford, Conn., the following is the general outline of the methods in use for preparing work for plating:—

*For cleansing (steel) cutlery.*—Immersion in boiling alkali for the removal of grease; scouring; rinsing; dipping into strong hydrochloric acid; then for a few seconds in a silver “striking” solution; then in a plating bath until the required amount of silver is deposited.

The formula for the “striking” solution, which will be given later on, is low in silver, rich in cyanide, and worked with a strong current and silver anode.

*Nickel-silver (German silver) for spoons.*—Immerse in boiling alkali; scouring, if necessary rinsing in water; immersion in acid mixture, composed of two-thirds sulphuric acid and one-third nitric acid; dipping in weak quicking solution (either very dilute potassium-mercury cyanide or acidulated nitrate of mercury); immersion for a few seconds in the silver “striking” solution; and from this into the plating bath.

*Britannia metal (hollow-ware).*—Cleansing in alkali as above; rinsing in water; again immersing in alkali to remove finger-marks, if necessary, immersing in the “striking” solution, and from this into the plating solution. A quicking solution for Britannia, sometimes employed, is composed of a strong solution of sal ammoniac and corrosive sublimate, into which the articles are dipped after cleansing in potash.

The silver “striking” solution, as used by the Wm. Rogers Manufacturing Co., of Hartford, Conn., is composed as follows:

*Rogers's “striking” solution.*—Cyanide of potassium, 6 ozs.; silver,  $\frac{1}{2}$  oz.; water, 1 gallon. Use a strong current.

*Meriden Company's “striking solution.”*—Cyanide of potassium, 12 to 16 ozs.; silver, 8 to 10 dwt.; water, 1 gallon.

The plating solution commonly employed by the Wm. Rogers Manufacturing Co., has the following composition: Cyanide of potassium, 6 ozs.; silver (in chlorate), 4 ozs.; water, 1 gallon.

The usual formula of the Meriden Britannia Co., has the following proportions: Cyanide of potassium, 12 ozs.; silver, 3 ozs.; water, 1 gallon.

In order to secure an extra heavy coating of silver on the convex surfaces of spoons and forks, which, being subject to greater wear than the other parts, require extra protection, the Meriden Britannia Co. uses a frame in which the articles supported therein by their tips are placed horizontally in a shallow silver bath, and immersed just deep enough to allow the projecting convexities to dip into the bath. By this artifice these portions are given a second coating of silver of any desired thickness. This mode of procedure, which is termed "sectional" plating, accomplishes the intended purpose nicely and satisfactorily. In some establishments the silvered forks and spoons are placed between plates of gutta-percha of corresponding shape, and held together by rubber bands. In these plates the portions to be provided with an extra coating of silver are cut out. By suspending the forks and spoons thus protected in the bath, the unprotected places receive a further layer of silver, the outlines of which are later on smoothed down with burnishers. The second object may also be attained by coating the places which are to receive no further deposit with "stopping-off" varnish (see below).

*Stopping off.*—If certain parts of a metallic article are not to receive a deposit, as for instance, when a contrast is to be effected by depositing different metals upon the same object, these parts are covered or "stopped-off," with a varnish. Stopping-off varnish is prepared by dissolving asphalt or dammar with an addition of mastic in oil of turpentine. Apply with a brush, and after thoroughly drying the articles in the drying-chamber, place them for an hour in very cold water, whereby the varnish hardens completely. After plating, the varnish is removed, best with benzine, the article plunged in hot water, and dried in saw-dust.

For a varnish that will resist the solvent power of the hot alkaline gilding liquid, Gore recommends the following compo-



sition: Translucent rosin 10 parts, yellow beeswax 6, extra-fine red sealing-wax 4, finest polishing rouge 3.

Quick-drying stopping-off varnishes, which harden immediately at the ordinary temperature, and resist cyanide baths, are now found in commerce.

*Silvering by contact, by immersion, and cold stirring with paste.*—For silvering by contact with zinc, the bath prepared according to formula II, may be used, adding about 17 grains more of potassium cyanide per quart. The articles are to be prepared in the same manner as for plating by weight, and quicked in a weak quicking solution. Before placing the articles in the bath they are wrapped round with bright zinc wire, or are brought in contact while in the bath with a bright strip of zinc, care being had to frequently change the points of contact to prevent the formation of stains. As previously mentioned, by the contact of the metal to be silvered with the electro-positive zinc, a weak current is produced which effects the deposition of the silver; but as this takes place very slowly, it is best to heat the silver bath. Silver being at the same time deposited upon the zinc, the latter must be frequently freed from the deposit and brightened by means of a file or emery paper.

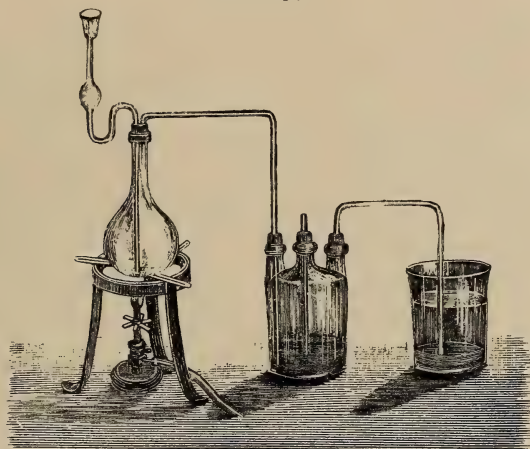
By contact with zinc, silver may also be deposited in one of the following baths for *silvering by immersion*.

Crystallized nitrate of silver 5.64 drachms, 98 per cent. potassium cyanide 1.23 ozs., distilled water 1 quart. To prepare the bath dissolve the silver salt in 1 pint of the water, then the potassium cyanide in the remaining pint of water, and mix the two solutions. The bath is heated in a porcelain or enameled iron vessel to between 176° and 194° F., and the thoroughly cleansed and pickled objects are immersed in it until uniformly coated, previous quicking being not required. The deposit is lustrous if the articles are left but a short time in the bath, but becomes dull when they remain longer. In the first case the deposit is a mere film, and, while it is somewhat thicker in the latter, it can under no circumstances be called solid.

The bath gradually works less effectively and finally ceases to silver, when its action may be restored by the addition of  $2\frac{3}{4}$  to  $5\frac{1}{2}$  drachms of potassium cyanide per quart. Should this prove ineffectual, the content of silver is nearly exhausted, and the bath is evaporated to dryness, and the residue added to the silver waste. Frequent refreshing of the bath with silver salt cannot be recommended, the silvering always turning out best in a fresh bath.

A solution of nitrate of silver in sodium sulphide is, according to Roseleur, very suitable for silvering by immersion. The

FIG. 134.



solution is prepared by pouring into a moderately concentrated solution of sodium sulphide, while constantly stirring, solution of a silver salt until the precipitate of silver sulphide formed begins to be dissolved with difficulty. This bath can be used cold or warm, fresh solution of silver being added when it commences to lose its effect. If, however, the bath is not capable of dissolving the silver sulphide formed, concentrated solution of sodium sulphide has to be added.

For the preparation of the solution of sodium sulphide, Roseleur recommends the following method:—

Into a tall vessel of glass or porcelain (Fig. 134) introduce 5

quarts of water and 4 pounds of crystallized soda, after pouring in mercury about an inch or so deep to prevent the glass tube through which the sulphurous acid is introduced from being stopped up by crystals. The sulphurous acid is evolved by heating copper turnings with concentrated sulphuric acid, washing the gas in a Woulff bottle filled an inch or so deep with water, and introducing it into the bottle containing the soda solution, as shown in the illustration. A part of the soda becomes transformed into sodium sulphide, which dissolves, and a part is precipitated as carbonate. The latter, however, is transformed into sodium sulphide by the continuous action of sulphurous acid, and carbonic acid gas escapes with effervescence. When all has become dissolved, the introduction of sulphurous acid should be continued until the liquid slightly reddens blue litmus paper, when it is set aside for 24 hours. At the end of that time a certain quantity of crystals will be found upon the mercury, and the liquid above, more or less colored, constitutes the sodium sulphide of the silvering bath. The liquid sodium sulphide thus prepared should be stirred with a glass rod, to eliminate the carbonic acid which may still remain in it. The liquid should then be again tested with blue litmus paper; and if the latter is strongly reddened, carbonate of soda is cautiously added, little by little, in order to neutralize the excess of sulphurous acid. On the other hand, if red litmus paper becomes blue, too much alkali is present, and more sulphurous acid gas must be passed through the liquid, which is in the best condition for our work when it turns litmus-paper violet or slightly red. The solution should mark from  $22^{\circ}$  to  $26^{\circ}$  Bé., and should not come in contact with iron, zinc, tin, or lead.

As will be seen, this mode of preparing the sodium sulphide solution is somewhat troublesome, and it is therefore recommended to proceed as follows: Prepare a saturated solution of commercial sodium sulphide. The solution will show an alkaline reaction, the commercial salt frequently containing some sodium carbonate. To this solution add, while stirring, solu-

tion of bisulphide of sodium saturated at  $122^{\circ}$  F., until blue litmus paper is slightly reddened. Then add to this solution concentrated solution of nitrate of silver until the flakes of silver sulphide separated begin to dissolve with difficulty.

The immersion-bath, prepared according to one or the other method, works well, the silvering produced having a beautiful lustre, such as is desirable for many cheap articles. If the articles are allowed to remain for a longer time in the bath, a matt deposit is obtained. For bright-silvering, the bath should always be used cold. It must further be protected as much as possible from the light, otherwise gradual decomposition takes place.

According to Dr. Ebermayer, a silver-immersion bath for bright silvering is prepared as follows: Dissolve 1.12 ozs. of nitrate of silver in water, and precipitate the solution with caustic potash. Thoroughly wash the silver oxide which is precipitated, and dissolve it in 1 quart of water which contains 3.52 ozs. of potassium cyanide in solution, and finally dilute the whole with one quart more water. For silvering, the bath is heated to the boiling point, and the silver withdrawn may be replaced by the addition of moist silver oxide as long as complete solution takes place. When the silvering is no longer beautiful and of a pure white color, the bath is useless, and is then evaporated. Experiments with a bath prepared according to the above directions were not satisfactory, the coating being dull and adhering badly.

For silvering articles, especially those composed of the various alloys of copper, without the use of a current, the following process is recommended in "*Edelmetallindustrie*." Dissolve silver in nitric acid with the assistance of the sand or water bath, and convert it into chloride of silver by carefully adding hydrochloric acid or common salt solution until, after repeated stirring and allowing to settle, no more precipitate is formed. Now let the mixture repose, then pour off the supernatant fluid and wash the white caseous precipitate until litmus-paper is no longer reddened by the wash-water. Keep the chloride of silver



thus obtained in wide-mouthed black bottles. Now prepare in glazed pots two baths as follows: 1. A potassium-cyanide bath by dissolving  $11\frac{1}{4}$  drachms of chloride of silver and 2 ozs. of potassium cyanide in about 10 quarts of water, and heating the mixture to the boiling point. 2. A salt bath consisting of 10 quarts of water, 11 lbs. of common salt, 11 lbs. of cream of tartar, and  $4\frac{1}{2}$  ozs. of chloride of silver. Boil the mixture, with constant stirring, for one hour, and when cold pour it into another pot, in which it may be kept. The articles to be silvered are cleansed by treating them with dilute hydrochloric acid. They are next pickled by dipping them in nitric acid, and finally plunged into a *bright-dipping bath*, consisting of nitric acid, a small quantity of hydrochloric acid and a trace of lamp-black. They are then thoroughly rinsed off, and thrown into water containing a small quantity of cream of tartar, where they remain until they are silvered. The water must not be warm and the articles should not remain in it too long, otherwise they will tarnish and it will be impossible to obtain a pure silvering. The articles thus prepared are first brought into the potassium-cyanide bath and gently agitated, when they become immediately coated with a thin film of silver. They are then rinsed and brought into a dilute salt bath, prepared by adding water to a portion of the salt given under 2, where they remain until they have acquired a gray-white or yellowish-white color. They are then rinsed, returned to the potassium-cyanide bath, again rinsed and thrown into clean water, or dried in sawdust. Each rinsing must be effected in a different vessel. The two baths are very lasting, and require only a periodical addition of potassium cyanide (when the articles on being immersed become black, which turns slowly to white), or of chloride of silver (when the articles show a yellowish-white color). When the dilute salt bath becomes too weak, a fresh quantity of the salt bath is added by means of a wooden spoon. The potassium-cyanide bath must every day be agitated. During the process of silvering the potassium-cyanide bath is to be kept at between  $176^{\circ}$  and  $194^{\circ}$  F., and the salt bath at above  $212^{\circ}$

F. The potassium-cyanide bath should only be boiled before use, when making a fresh addition of potassium cyanide, or of chloride of silver. The silvering obtained is pure white, cheap and durable.

The process of coating with a thin film, or rather whitening with silver, small articles, such as hooks and eyes, pins, etc., differs from the above-described immersion method, which affects the silvering in a few seconds, in that the articles require to be boiled for a longer time. The process is as follows: Prepare a paste from 14.11 drachms of nitrate of silver, precipitated as chloride of silver; 44 ounces of cream of tartar, and a like quantity of common salt, by precipitating the solution of the nitrate of silver with hydrochloric acid, washing the chloride of silver and mixing it with the above-mentioned quantities of cream of tartar and common salt, and sufficient water to a paste, which is kept in a dark glass vessel to prevent the chloride of silver from being decomposed by the light. Small articles of copper or brass are first freed from grease, and pickled. Then heat in an enameled kettle 3 to 5 quarts of rain-water to the boiling point; add 2 or 3 heaping teaspoonfuls of the above-mentioned paste, and bring the metallic objects contained in a stoneware sieve into the bath and stir them diligently with a rod of glass or wood. Before placing a fresh lot of articles in the bath additional silver paste must be added. If finally the bath acquires a greenish color, caused by dissolved copper, it is no longer suitable for the purpose, and is then evaporated and added to the silver residues.

*Cold silvering with paste.*—In this process an argentiferous paste, composed as given below, is rubbed, by means of the thumb, a piece of soft leather or rag, upon the cleansed and pickled metallic surface (copper, brass, or other alloys of copper) until it is entirely silvered. The paste may also be rubbed in a mortar with some water to a uniform thinly-fluid mass, and applied with a brush to the surface to be silvered. By allowing the paste to dry naturally, or with the aid of a gentle heat, the silvering appears. The application of the paste

by means of a brush is chiefly made use of for decorating with silver, articles thinly gilded by immersion. For articles not gilded, the above-mentioned rubbing on of the stiff paste is to be preferred.

*Composition of argentiiferous paste.*—I. Silver in the form of freshly precipitated chloride of silver,\* 0.35 oz. common salt 0.35 oz., potash 0.7 oz., whiting 0.52 oz., and water a sufficient quantity to form the ingredients into a stiff paste.

II. Silvering in the form of freshly precipitated chloride of silver \* 0.35 oz., potassium cyanide 1.05 ozs., sufficient water to dissolve these two ingredients to a clear solution, and enough whiting to form the whole into a stiff paste. This paste is also excellent for polishing tarnished silver; it is, however, poisonous.

The following non-poisonous composition does excellent service: Silver in the form of chloride of silver 0.35 oz., cream of tartar 0.7 oz., common salt 0.7 oz., and sufficient water to form the mixture of the ingredients into a stiff paste.

Another composition is as follows: Chloride of silver 1 part, pearl-ash 3, common salt  $1\frac{1}{2}$ , whiting 1, and sufficient water to form a paste. Apply the latter to the metal to be silvered and rub with a piece of soft leather. When the metal is silvered, wash in water to which a small quantity of washing soda has been added.

*Graining.*—In gilding parts of watches, gold is seldom directly applied upon the copper; there is generally a preliminary operation called graining, by which a grained and slightly dead appearance is given to the articles. Marks of the file are obliterated by rubbing upon a whetstone, and lastly upon an oil-stone. Any oil or grease is removed by boiling the parts for a few minutes in a solution of 10 parts of caustic soda or potash in 100 of water, which should wet them entirely if all the oil has been removed. The articles being threaded upon a brass wire, cleanse them rapidly in the acid mixture for a bright

\* From 0.56 oz. of nitrate of silver.

lustre, and dry them carefully in white wood sawdust. The pieces are fastened upon the even side of a block of cork by brass pins with flat heads. The parts are then thoroughly rubbed over with a brush entirely free from grease, and dipped into a paste of water and very fine pumice-stone powder. Move the brush in circles, in order not to rub one side more than the other; thoroughly rinse in cold water, and no particle of pumice-stone should remain upon the pieces or the cork. Next place the cork and the pieces in a weak mercurial solution, composed of water  $2\frac{1}{2}$  gallons, nitrate or binocide of mercury  $\frac{1}{14}$  oz., sulphuric acid  $\frac{1}{7}$  oz., which slightly whitens the copper. The pieces are passed quickly through the solution and then rinsed. This operation gives strength to the graining, which without it possesses no adherence.

The following preparations may be used for graining: I. Silver in impalpable powder 2 ozs., finely pulverized cream of tartar 20 ozs., common salt 4 lbs. II. Silver powder 1 oz., cream of tartar 4 to 5 ozs., common salt 13 ozs. III. Silver powder, common salt, and cream of tartar, equal parts by weight of each. The mixture of the three ingredients must be thorough and effected at a moderate and protracted heat. The graining is the coarser the more common salt there is in the mixture, and it is the finer and more condensed as the proportion of cream of tartar is greater, but it is then more difficult to scratch-brush. The silver powder is obtained as follows: Dissolve in a glass or porcelain vessel  $\frac{2}{3}$  oz. of crystallized nitrate of silver in  $2\frac{1}{2}$  gallons of distilled water, and place 5 or 6 ribands of cleansed copper,  $\frac{3}{4}$  inch wide, in the solution. These ribands should be long enough to allow of a portion of them being above the liquid. The whole is kept in a dark place, and from time to time stirred with the copper ribands. This motion is sufficient to loosen the deposited silver, and present fresh surfaces to the action of the liquor. When no more silver deposits on the copper the operation is complete, and there remains a blue solution of nitrate of copper. The silver powder is washed by decantation or upon a filter until there remains nothing of the copper solution.



For the purpose of graining, a thin paste is made of one of the above mixtures and water, and spread by means of a spatula upon the watch parts held upon the cork. The cork itself is placed upon an earthenware dish, to which a rotating movement is imparted by the left hand. An oval brush with close bristles, held in the right hand, rubs the watch parts in every direction, but always with a rotary motion. A new quantity of paste is added two or three times and rubbed in the manner indicated. The more the brush and cork are turned the rounder becomes the grain, which is a good quality, and the more paste added the larger the grain. When the desired grain is obtained the pieces are washed and scratch-brushed. The brushes employed are of brass wire, as fine as hair, and very stiff and springy. It is necessary to anneal them upon an even fire to different degrees; one soft or half annealed for the first operation or uncovering the grain; one harder for bringing up the lustre; and one very soft or fully annealed, used before gilding for removing any marks which may have been made by the preceding tool, and for scratch-brushing after gilding, which, like the graining, must be done by giving a rotary motion to the tool. If it happens that the same watch part is composed of copper and steel, the latter metal requires to be preserved against the action of the cleansing acids and of the graining mixture by a composition called *resist*. This consists in covering the pinions and other steel parts with a fatty composition which is sufficiently hard to resist the tearing action of the bristle and wire brushes, and insoluble in the alkalies of the gilding bath. A good composition is: Yellow wax, 2 parts by weight; translucent rosin,  $3\frac{1}{2}$ ; extra fine red sealing-wax,  $1\frac{1}{3}$ ; polishing rouge, 1. Melt the rosin and sealing-wax in a porcelain dish, upon a water-bath, and afterwards add the yellow wax. When the whole is thoroughly fluid, gradually add the rouge and stir with a wooden or glass rod. Withdraw the heat, but continue the stirring until the mixture becomes solid, otherwise all the rouge will fall to the bottom. The flat parts to receive this resist are slightly heated, and then covered with the mix-

ture, which melts and is easily spread. For covering steel pinions employ a small gouge of copper or brass fixed to a wooden handle. The metallic part of the gouge is heated upon an alcohol lamp and a small quantity of resist is taken with it. The composition soon melts, and by turning the tool around the steel pinion thus becomes coated. Use a scratch-brush with long wires, as their flexibility prevents the removal of the composition. When the resist is to be removed after gilding, put the parts into warm oil or tepid turpentine, then into a very hot soap-water or alkaline solution; and, lastly, into fresh water. Scratch-brush and dry in warm, white wood sawdust. The holes of the pinions are cleansed and polished with small pieces of very white, soft wood, the friction of which is sufficient to restore the primitive lustre. The gilding of parts of copper and steel requires the greatest care, as the slightest rust destroys their future usefulness. Should some gold deposit upon the steel, it should be removed by rubbing with a piece of wood and impalpable pumice dust, tin-putty, or rouge.

The gilding of the grained watch parts is effected in a bath prepared according to formula I. or III., given under "Deposition of Gold."

*Silvering of fine copper wire* is effected in an apparatus similar to that shown in Fig. 125, p. 239, a reservoir containing potassium cyanide solution for pickling the cleansed wire being added and placed in front of the silver bath. Lustre is imparted to the silvered wire by drawing through a draw-plate. Further details will be found under "Deposition of Gold."

*Incrustations with silver, gold, and other metals.*—By incrusting is understood the inlaying of depressions, produced by engraving or etching upon a metallic body, with silver, gold, and other metals, such as Japanese incrustations, which are made by mechanically pressing the silver or gold into the depressions. Such incrustations, however, can also be produced by electro-deposition, the process being as follows: The design which is to be incrustated upon a metal is executed with a pigment of white-lead and glue-water or gum-water. The portion

not covered by the design is then coated with stopping-off varnish. The article is next placed in dilute nitric acid, whereby the pigment is first dissolved, and next the surface etched, which is allowed to progress to a certain depth. Etching being finished, the article is washed in an abundance of water and immediately brought into a silver or gold bath, in which, by the action of the current, the exposed places are filled up with metal. This being done, the "stopping-off" varnish is removed with benzine, the surface ground smooth, and polished. In this manner one article may be incrustated with several metals; for instance, brass may be incrustated with copper, silver, and gold, and by oxidizing or coloring portions of the copper beautiful effects can be produced. The principal requisites for these incrustations are manual skill and much patience. Expensive apparatus is not required, every skilled electro-plater being able to execute the work.

*Imitation of niel or nielled silvering.*—By nielling is understood the inlaying of designs produced either by engraving or stamping, with a black mixture of metallic sulphides. The nielling powder is prepared by melting, silver 20 parts by weight, copper 90 parts, and lead 150 parts. To the liquid metallic mass add  $26\frac{1}{2}$  ozs. of sulphur and  $\frac{3}{4}$  oz. of sal ammoniac, quickly cover the crucible, and continue heating until the excess of sulphur is volatilized. Then pour the contents of the crucible into another crucible, the bottom of which is covered about  $\frac{1}{3}$  inch deep with flowers of sulphur, cover the crucible and allow the mixture to cool. When cold bring the contents once more to the fusing point, and pour the fused mass in a thin stream into a bucket filled with water, whereby granulated metal is formed, which can be readily reduced in a mortar to a fine powder. This powder is mixed with sal ammoniac and gum-water to a thin paste. This paste is brought into the designs produced by engraving or stamping, and after drying burnt in a muffle. When cold any roughness is removed by grinding, and after polishing a sharp black design in white silver is obtained.

To imitate niel by electro-deposition, the design is executed upon the surface with a pigment consisting of white lead and glue or gum-water. The portions which are to remain free are coated with "stopping-off" varnish, and the design is uncovered by etching with very dilute nitric acid. The article is then brought as the anode into dilute solution of ammonium sulphide, while a small sheet of platinum connected to the negative pole is dipped into the solution. Sulphide of silver being formed, the design becomes rapidly black gray, and after removing the "stopping-off" varnish with benzine, stands out in sharp contrast from the white silver.

Upon *brass*, nielling may be imitated by silvering the article and then engraving the design, by which the silver is removed and the brass uncovered. The article is then brought into the black bright dip, by which the uncovered brass is colored black while the silvered portions remain unchanged. If portions in relief are to be made black, the silvering is removed by grinding, the article dipped into cream of tartar solution and then brought into the black bright dip. This process is largely employed by manufacturers of buttons when silvered buttons are to be supplied with the name of the firm and the quality number in black.

*Old (antique) silvering.*—To give silvered articles an antique appearance coat them with a thin paste of 6 parts graphite, 1 red ochre, and sufficient spirits of turpentine. After drying, gentle rubbing with a soft brush removes the excess of powder, and the reliefs are set off (discharged) by means of a rag dipped into alcohol.

A tone resembling antique silvering is also obtained by brushing the silvered articles with a soft brush moistened with very dilute alcoholic solution of chloride of platinum.

In order to impart the old silver tinge to small articles, such as buttons, rings, etc., they are agitated in the above-mentioned paste, and then "tumbled" with a large quantity of dry sawdust until the desired shade is obtained.

Many operators, at the present day, produce the antique



silvering by beginning with the oxidizing process described below, and setting off the reliefs by means of a hard brush and pumice-stone, or Spanish white. The last process is almost exclusively used for metallic mountings of books and albums.

With the use of the electric current and carbon anodes, antique silver may be produced as follows: Bring the silvered articles, previously thoroughly freed from grease, into the old silver bath at a current-tension of 4 to 5 volts, and allow them to remain for a few minutes until they become covered with a uniform blue-gray deposit. They are then thoroughly rinsed in water, and the raised portions rubbed with very fine pumice, to lay bare the silver. If surfaces are to appear in antique silver, the deposit is only sufficiently removed with pumice for the silver to shine through, and the surface to show the proper antique silver tone.

*Oxidized silver.* — This term is incorrect, as by it is understood not an oxidation, but a combination with sulphur or chlorine. Solution of pentasulphide of potassium (liver of sulphur of the shops) is generally used for the purpose. Immerse the articles in a solution of 2.75 drachms of liver of sulphur and  $5\frac{1}{2}$  drachms of ammonium carbonate in 1 quart of water heated to  $176^{\circ}$  F., and allow them to remain until they have acquired the desired dark tone. Immediately after immersion, the articles become pale gray, then darker, and finally, deep black-blue. For coloring in this manner, the silvering should not be too thin. For articles with a very thick deposit of silver, solution of double the strength may be used. Very slightly silvered articles cannot be oxidized in this manner, as the bath would remove the silvering, or under the most favorable circumstances produce only a gray color. If the operation is not successful, and the articles come from the bath stained, or otherwise defective, dip them in a warm potassium cyanide solution, which rapidly dissolves the silver sulphide formed.

A *yellow color* is imparted to silvered articles by immersion in a hot concentrated solution of chloride of copper, rinsing and drying.

*Stripping silvered articles.*—When a silvering operation has failed, or the silver is to be stripped from old silvered articles, different methods have to be used according to the nature of the basis-metal. Silvered *iron articles* are treated as the anode in potassium cyanide solution in water (1 : 20), the iron not being attacked by potassium cyanide. As cathode suspend in the solution a few silver anodes or a copper sheet rubbed with an oily rag; the silver precipitates upon the copper sheet, but does not adhere to it. Articles, the basis of which is *copper*, are best stripped by immersion in a mixture of equal parts of anhydrous (fuming) sulphuric acid and nitric acid of 40° Bé. This mixture makes the copper passive, it not being attacked while the silver is dissolved. Care must, however, be had not to introduce any water into the acids, nor to let them stand without being hermetically closed, since by absorbing moisture from the air they become dilute, and may then exert a dissolving effect upon the copper. The fuming sulphuric acid may also be heated in a shallow pan of enameled cast iron to between 300° and 400° F. Then, at the moment of using it, pinches of dry and pulverized nitrate of potassium (saltpetre) are thrown into it, and the article, held with copper tongs, is plunged into the liquid. The silver is rapidly removed, while the copper or its alloys is but slightly corroded. According to the rapidity of the solution, fresh additions of saltpetre are made. All the silver has been dissolved when, after rinsing in water and dipping the articles into the cleansing acids, they present no brown or black spots, that is to say, when they behave like new. In this hot acid stripping proceeds more quickly than in the cold acid mixture, but the latter acts more uniformly.

*Determination of silver-plating.*—By applying to genuine silver-plating a drop of nitric acid of 1.2 specific gravity, in which red chromate of potash has been dissolved to saturation, a red stain of chromate of silver is formed. According to Gräger, this method may also be used, to a certain extent, for the recognition of other white metal which may be mistaken

for silver. A drop of the mixture applied to *German silver* becomes brown, no red stain appearing after rinsing with water; upon *Britannia* the drop produces a black stain; *zinc* is etched without a colored spot remaining behind; upon *amalgamated* metals a brownish precipitate is formed, which does not adhere and is washed away by water; upon *tin* the drop also acquires a brownish color, and by diluting with water a yellow precipitate is formed; upon *lead* a beautiful yellow precipitate is formed.

Custom-house officers in Germany are directed by law to use the following process for the determination of genuine silver-plating: Wash a place on the article with ether or alcohol, dry with blotting paper, and apply to the spot thus cleansed a drop of a 1 to 2 per cent. solution of crystallized bisulphite of soda prepared by boiling 1.05 ozs. of sodium sulphite and 2.36 drachms of flowers of sulphur with 0.88 oz. of water until the sulphur is dissolved, and diluting to 1 quart of fluid. Allow the drop to remain upon the article about ten minutes and then rinse off with water. Upon silver articles, a full, round, steel-gray spot is produced. Other white metals and alloys, with the exception of amalgamated copper, do not show this phenomenon, there appearing at the utmost a dark ring at the edge of the drop. Amalgamated copper is more quickly colored, and acquires a more dead-black color than silver.

#### *Examination of Silver Baths.*

For the quantitative examination of silver baths, the determination of the content of free potassium cyanide and of metallic silver as well as of the potassium carbonate which is formed by the action of air, etc., upon the potassium cyanide, has to be taken into consideration.

Regarding the determination of the free potassium cyanide, the reader is referred to the method given under "Examination of copper baths containing potassium cyanide," and what has been said there in reference to replacing the deficiency also applies here.

The potassium carbonate which is formed in constantly increasing quantities in the bath is best removed by the addition of barium cyanide solution, whereby, in consequence of reciprocal decomposition, potassium cyanide is formed, while barium carbonate in an insoluble state is separated.

The determination of the potassium carbonate present in the bath is desirable, so as to be able, on the one hand, to calculate the quantity of barium cyanide required for its decomposition and, on the other, to become acquainted with the quantity of free potassium cyanide formed thereby.

The determination of the potassium carbonate is effected as follows: Bring by means of the pipette 20 cubic centimeters of the bath into a beaker, dilute with 50 cubic centimeters of water and compound with barium nitrate solution in excess. Allow to settle for some time, then filter through not too large a paper filter, taking care that the entire precipitate reaches the filter, and wash the filter thoroughly with water until a few drops of the filtrate, when evaporated upon a platinum sheet, leave no residue. Now take the filter, together with the residue, carefully from the funnel, bring it into a beaker, and add water, as well as a carefully measured quantity of standard nitric acid, which should, however, be somewhat larger than required for dissolving the barium carbonate. While solution is being effected, keep the beaker covered with a watch glass, and then rinse any drops appearing upon the latter into the beaker by means of distilled water. Add to the solution, as an indicator, a few drops of methyl-orange, whereby the solution is colored red, and add, while stirring constantly, from a burette, standard soda solution until the red color of the solution passes into yellow. By now deducting the cubic centimeters of soda solution used from the cubic centimeters of standard nitric acid added for the solution of the barium carbonate, and multiplying the number of the remaining cubic centimeters of standard nitric acid by 3.45, the quantity of potassium carbonate in grammes per liter of silver bath is obtained.



Now the quantity of barium cyanide has to be calculated which is required for the conversion of the quantity of potassium carbonate found into potassium cyanide with the separation of barium carbonate. It is best to use a 20-per cent. barium cyanide solution, and since 1 gramme of potassium carbonate requires for conversion 1.36 grammes of barium cyanide, 6.80 grammes of 20 per cent. barium cyanide solution are necessary for the purpose, and each gramme of potassium cyanide yields 0.942 gramme of potassium cyanide. Hence for the determination of the potassium cyanide present after the destruction of the potassium carbonate, there has to be added to the potassium cyanide found by titration, the content of free potassium cyanide calculated from the conversion with barium cyanide. If this shows a deficit as compared with the original content, it is to be made up by adding only about one-half the quantity, for the same reason as given in speaking of the copper bath, namely, because the potassium formate, which is at the same time formed, performs the function of the potassium cyanide.

*For the determination of the silver*, the electrolytic method is the most simple and suitable in so far as the silver bath can be directly used for the purpose.

Bring by means of the pipette into the platinum dish 10 cubic centimeters of the silver bath, or 20 cubic centimeters if the bath is weak, add, according to the greater or smaller excess of the potassium cyanide present,  $\frac{1}{2}$  to 1 gramme of potassium cyanide dissolved in water, and dilute up to 1 or  $1\frac{1}{2}$  centimeters from the edge of the dish. Heat, by means of a small flame, the contents of the dish to from  $140^{\circ}$  to  $149^{\circ}$  F., and maintain this temperature as nearly constant as possible. Electrolysis is effected with a current-density  $ND_{100} = 0.08$  ampère. Complete precipitation, which requires 3 to  $3\frac{1}{2}$  hours, is recognized by ammonium sulphide producing no dark coloration of the fluid. The dish is then washed, without interrupting the current, rinsed with alcohol and ether, dried for a short time at  $212^{\circ}$  F., and weighed. The weight of the pre-

cipitate multiplied by 100 gives the content of silver in grammes per liter of bath. If 20 cubic centimeters of silver bath have been electrolyzed, multiply only by 50.

If the analysis has shown a deficit of silver in the bath, it can be readily replaced. For strengthening the bath it is best to use pure crystallized potassium silver cyanide, which in round numbers contains 50 per cent. of silver. Suppose the bath contains per liter 2 grammes of silver less than it should, then for each liter of bath ( $52:100=2:x$ ;  $x=3.8$  grammes), 3.8 grammes of pure crystallized potassium silver cyanide have to be added.

The more troublesome volumetric analysis may be omitted, it offering no advantage over the electrolytic method.

*Recovery of silver from old silver baths, etc.* — Old solutions which contain silver in the form of a silver salt are easily treated. It is sufficient to add to them, in excess, a solution of common salt, or hydrochloric acid, when all the silver will be precipitated in the state of chloride of silver, which, after washing, may be employed for the preparation of new baths.

For the recovery of silver from solutions which contain it as cyanide, the solutions may be evaporated to dryness, the residue mixed with a small quantity of calcined soda and potassium cyanide, and fused in a crucible, whereby metallic silver is formed, which, when the heat is sufficiently increased, will be found as a button upon the bottom of the crucible; or if it is not desirable to heat to the melting-point of silver, the fritted mass is dissolved in hot water, and the solution containing the soda and cyanide quickly filtered off from the metallic silver. The evaporation of large quantities of fluid, to be sure, is inconvenient, and requires considerable time. But the reducing process above described is without doubt the most simple and least injurious.

According to the *wet method*, the bath is strongly acidulated with hydrochloric acid, provision being made for the effectual carrying off of the hydrocyanic acid liberated. Remove the precipitated chloride of silver and cyanide of copper by filtra-

tion, and, after thorough washing, transfer it to a porcelain dish and treat it, with the aid of heat, with hot hydrochloric acid, which will dissolve the cyanide of copper. The resulting chloride of silver is then reduced to the metallic state by mixing it with four times its weight of crystallized carbonate of soda, and half its weight of pulverized charcoal. The whole is made into a homogeneous paste, which is thoroughly dried, then introduced into a strongly heated crucible. When all the material has been introduced, the heat is raised to promote complete fusion, and to facilitate the collection of the separate globules of silver into a single button at the bottom of the crucible, where it will be found after cooling. If granulated silver is wanted, pour the metal in a thin stream, and from a certain height into a large volume of water.

A very simple method is as follows: Bring the silver bath into flasks, mix the contents of the flasks with zinc dust (zinc in a finely divided state) in the proportion of about  $\frac{1}{3}$  oz. per quart of bath, and shake thoroughly 5 or 6 times every day. In five days all the silver is precipitated. Decant the clear liquid from the precipitate, wash the latter several times with water, and dissolve the zinc contained in the precipitate in pure hydrochloric acid. The silver remains behind in pulverulent form, and may be dissolved in nitric acid, worked up into silver chloride or silver cyanide. In place of zinc, aluminium powder may be used for precipitation, the excess of aluminium being then dissolved by caustic potash, or caustic soda, solution.

From acid mixtures used for stripping, the silver may be obtained as follows: Dilute the acid mixture with 10 to 20 times the quantity of water, and precipitate the silver as chloride of silver by means of hydrochloric acid. Interrupt the addition of hydrochloric acid, when a drop of it produces no more precipitate of chloride of silver in the clear fluid. The precipitated chloride of silver is filtered off, washed, and either directly dissolved in potassium cyanide, or the silver is regained as metal by fusing the chloride of silver with calcined soda and wood charcoal powder, previously thoroughly mixed.

Still simpler is the reduction of the chloride of silver by pure zinc. For this purpose suspend the chloride of silver in water, add hydrochloric acid, and place pure zinc rods or granulated zinc in the fluid. The zinc dissolving, metallic silver is separated, which is filtered off, washed and dried.



## CHAPTER X.

### DEPOSITION OF GOLD.

GOLD is chiefly found in the metallic state, and generally alloyed with more or less silver, copper and iron. The following analyses will serve to show the general composition of the native metal:—

	Australia.	California.	Russia.	Wales.
Gold .....	94.64	89.10	98.96	89.83
Silver.....	4.95	10.50	0.16	9.24
Copper .....	....	....	0.05	....
Iron.....	0.41	0.20	0.35	....
	<hr/> 100.00	<hr/> 99.80	<hr/> 99.52	<hr/> 99.07

Gold is one of the few metals possessing a yellow color. Precipitated from its solution with green vitriol or oxalic acid, it appears as a brown powder without lustre, which on pressing with the burnisher acquires the color and lustre of fused gold. Pure gold is nearly as soft as lead, but possesses considerable tenacity. In order to increase its hardness when used for articles of jewelry and for coinage it is mixed with silver or copper. The “fineness of gold,” or its proportion in the alloy, is usually expressed by stating the number of carats present in 24 carats of the mixture. Pure gold is stated to be 24 carats “fine;” standard gold is 22 carats “fine;” 18 carat gold is a mixture of 18 parts of gold and 6 of alloy. Gold is the most malleable and ductile of the metals; it may be beaten out into leaves not exceeding  $\frac{1}{10,000}$ th of a millimeter in thickness. When beaten out into thin leaves and viewed by transmitted light gold appears green; when very finely divided it is dark red or black. The specific gravity of fused gold is 19.35, and of precipitated gold powder from 19.8 to 20.2. Pure gold melts at about 2016° F., and in fusing exhibits a sea-green color. The melt-

ing-points of alloyed gold vary according to the degree of fineness. Thus, 23 carat gold melts at  $2012^{\circ}$  F.; 22 carat at  $2009^{\circ}$ ; 20 carat at  $2002^{\circ}$ ; 18 carat at  $1995^{\circ}$ ; 15 carat at  $1992^{\circ}$ ; 13 carat at  $1990^{\circ}$ ; 12 carat at  $1987^{\circ}$ ; 10 carat at  $1982^{\circ}$ ; 9 carat at  $1979^{\circ}$ ; 8 carat at  $1973^{\circ}$ ; 7 carat at  $1960^{\circ}$ . The fineness of gold may be approximately estimated by means of the *touch-stone*, a basaltic stone formerly obtained from Asia Minor, but now procured from Saxony and Bohemia. The sample of gold to be tested is drawn across the stone, and the streak of metal is treated with dilute nitric acid. From the rapidity of the action and the intensity of the green color produced—due to the solution of the copper—as compared with streaks made by alloys of known composition, the assayer is enabled to judge of the proportion of inferior metal which is present. Gold preserves its lustre in the air and is not acted upon by any of the ordinary acids. Nitric, hydrochloric, or sulphuric acid by itself does not dissolve gold, but it dissolves in acid mixtures which develop chlorine, hence in aqua regia (nitro-hydrochloric acid).

The gold found in commerce under the name of *shell-gold* or *painter's gold*, which is used in painting and for repairing smaller defects in electro gilding, is prepared by triturating waste in the manufacture of leaf gold with water, diluted honey or gum-water. Gold solution may also be precipitated with antimoniac chloride. The resulting precipitate is triturated with barium hydrate, extracted with hydrochloric acid, and after washing, the gold powder is triturated with gum arabic solution.

*Gold baths.* Gold-plating may be effected in a hot or cold bath, large objects being generally plated in the latter, and smaller objects in the former. The hot bath has the advantage of requiring less current-strength, besides yielding deposits of greater density and uniformity and of sadder, richer tones. Hot baths work with a moderate content of gold— $11\frac{1}{2}$  to  $12\frac{1}{2}$  grains per quart of bath—while cold baths should contain not less than 54 grains per quart.

Some authors—for instance, Elsner, Briant, Selm, and others

—give the preference to baths prepared with potassium ferrocyanide; while others, like Elkington and Regnault, work with a solution of gold-salt and potassium bicarbonate; and Böttger, Leuchtenberg, and others recommend a solution of cyanide of gold in potassium cyanide. With proper treatment of the bath, good results may be obtained with either. However, the use of baths prepared with potassium ferrocyanide cannot be recommended on account of the secondary decompositions which take place during the operation of plating, and because the baths do not dissolve the gold anodes. In the following, only approved formulæ for the preparation of gold baths will be given:—

I. *Bath for cold gilding.*—Fine gold in the form of fulminating gold 54 grains, 98 per cent. potassium cyanide 0.35 to 0.5 oz. (according to the current-strength used), water 1 quart.

To prepare this bath, dissolve 54 grains of fine gold in aqua regia in a porcelain dish heated over a gas or alcohol flame, and evaporate the solution to dryness. Continue the heating until the solution is thickly fluid and dark brown, and on cooling congeals to a dark brown, foliated mass. Heating too strongly should be avoided, as this would cause decomposition and the auric chloride would be converted into aurous chloride, and eventually into metallic gold and escaping chlorine. The neutral chloride of gold prepared in this manner is dissolved in 1 pint of water and aqua ammonia added to the solution as long as a yellow-brown precipitate is formed, avoiding, however, a considerable excess of aqua ammonia. The precipitate of fulminating gold is filtered off, washed, and dissolved in 1 quart of water containing 0.5 oz. of potassium cyanide in solution. The solution is boiled, replacing the water lost by evaporation, until the odor of ammonia which is liberated by dissolving the fulminating gold in potassium cyanide disappears, when it is filtered. Instead of dissolving the gold and preparing neutral chloride of gold by evaporating, it is more convenient to use 108 grains of chemically pure neutral chloride of gold as furnished by chemical works, and precipitate the fulminating gold from its solution.

Too large an excess of potassium cyanide yields gold deposits of an ugly, pale color. When working with a more powerful current, the excess of potassium cyanide need only be slight; with a weaker current it must be larger. With 10 per cent. excess of free potassium cyanide, the most suitable current-strength is 3 volts.

The fulminating gold should not be dried, as in this condition it is highly explosive, but should be immediately dissolved while in a moist state.

For cold gilding, Roseleur recommends the following bath:

II. Fine gold as neutral chloride of gold, 0.35 oz.; 98 per cent. potassium cyanide, 0.7 oz.; water, 1 quart.

Dissolve the gold-salt from 0.35 oz. of fine gold or about 0.7 oz. of neutral chloride of gold in  $\frac{1}{2}$  pint of the water, and the potassium cyanide in the other  $\frac{1}{2}$  pint of water, and after mixing the solutions boil for half an hour. The preparation of this bath is more simple than that of formula I., but the color of the gold deposit obtained with the latter is warmer and sadder. The high content of gold in the bath, prepared according to formula II., readily causes a red-brown gold deposit, and hence special attention has to be paid to the regulation of the current.

For those who prefer gold baths prepared with yellow prussiate of potash instead of potassium cyanide, the following formula for *cold gilding* is given:

III. Yellow prussiate of potash (potassium ferrocyanide), 0.5 oz.; carbonate of soda, 0.5 oz.; fine gold (as chloride of gold or fulminating gold), 30.75 grains; water, 1 quart.

To prepare the bath, heat the solutions of the yellow prussiate of potash and of the carbonate of soda in the water to the boiling point, add the gold-salt, and boil  $\frac{1}{4}$  hour, or with use of freshly precipitated fulminating gold, until the odor of ammonia disappears. After cooling, the solution is mixed with a quantity of distilled water, corresponding to the water lost by evaporation, and filtered. This bath gives a beautiful bright gilding upon all metals, even upon iron and steel.



This bath is especially suitable for the so-called French gilding. The articles are first provided with a heavy deposit of copper in the alkaline copper bath, then matt coppered in the acid copper bath, next drawn through the bright-pickling bath, thoroughly rinsed, and finally gilded in the bath heated to about 122° F. Suitable current-strength for the cold bath 3.0 to 3.25 volts; for the warm bath, 1.5 to 2 volts.

*Gold bath for hot gilding.*—IV. Fine gold (as fulminating gold) 15.4 grains, 98 per cent. potassium cyanide 77 grains, water 1 quart.

This bath is prepared in the same manner as that according to formula I., from 15.4 grains of fine gold, which is converted into neutral chloride of gold by dissolving in aqua regia and evaporating; or dissolve directly 29.32 to 30.75 grains of chemically pure neutral chloride of gold in water, precipitate the gold as fulminating gold with aqua ammonia, wash the precipitate, dissolve it in water containing the potassium cyanide, and heat until the odor of ammonia disappears, replacing the water lost by evaporation. This bath yields a beautiful sad gilding of great warmth. All that has been said in regard to the content of potassium cyanide in the bath prepared according to formula I. also applies to this bath. The temperature should be between 158° and 176° F., and the current-strength 2.0 to 2.5 volts.

Roseleur recommends for hot electro-gilding:

V. Chemically pure crystallized sodium phosphate 2.11 ozs., neutral sodium sulphide 0.35 oz., potassium cyanide 30.86 grains, fine gold (as chloride) 15.43 grains, distilled water 1 quart.

If this bath is to serve for directly plating *steel*, only 15.43 instead of 30.86 grains of potassium cyanide are to be used. Dissolve in a porcelain dish, with the aid of moderate heat, the sodium phosphate and sodium sulphide, and when the solution is *cold*, add the neutral chloride of gold prepared from 15.43 grains of gold = about 30.86 grains of commercial chloride of gold, and the potassium cyanide. For use, heat the bath to between 158° and 167° F.

Conrad Taucher recommends the following formulæ for hot gilding:—

VI. Sodium phosphate 14 ozs., sodium bisulphite  $3\frac{1}{2}$  ozs., sodium bicarbonate  $1\frac{3}{4}$  ozs., caustic potash  $1\frac{3}{4}$  ozs., potassium cyanide 14 drachms, gold in the form of neutral chloride  $8\frac{1}{2}$  drachms, distilled water 10 quarts.

With the exception of the chloride of gold, all the salts may be dissolved together. The solution, if necessary, is filtered and the gold solution added. The bath is used at between  $122^{\circ}$  and  $140^{\circ}$  F. It yields a very beautiful gilding, but requires quite a strong current for its decomposition. It is not suitable for the direct gilding of steel.

VII. Yellow prussiate of potash (potassium ferrocyanide)  $5\frac{1}{4}$  ozs., pure potassium carbonate  $1\frac{3}{4}$  ozs., sal ammoniac  $11\frac{1}{4}$  drachms, gold in the form of neutral chloride  $5\frac{1}{2}$  drachms, water 5 quarts.

Dissolve with the assistance of heat the first three salts, filter, and when cold add the chloride of gold. Then heat again and boil for half an hour, replacing the water lost by evaporation.

Many electro-platers prepare the gold baths with the assistance of the electric current. For this purpose prepare a solution of 3.52 ozs. of potassium cyanide (98 to 99 per cent.) per quart of water, and after heating to between  $122^{\circ}$  and  $140^{\circ}$  F., conduct the current of two Bunsen elements through two sheets of gold, not too small, which are suspended as electrodes in the potassium cyanide solution. The action of the current is interrupted when the solution is so far saturated with gold that an article immersed in it and connected to the negative pole in place of the other gold sheet, is gilded with a beautiful warm tone. By weighing the sheet of gold serving as anode, the amount of gold which has passed into the solution is ascertained. According to English authorities, a good gold bath prepared according to this method should contain 3.52 ozs. of potassium cyanide and 0.7 oz. of fine gold per quart of water.

The only advantage of this mode of preparing the bath is that it excludes a possible loss of gold, which may occur in dissolv-

ing gold, evaporating the gold solution, etc., by breaking the vessel containing the solution. However, by using commercial chemically pure chloride of gold such loss is avoided, and the bath prepared according to the formulæ given yields richer tones than a gold bath produced by electrolysis. Besides, the preparation of the gold bath with the assistance of the electric current can only be considered for smaller baths, since the saturation of a larger volume of potassium cyanide solution requires considerable time, and the potassium cyanide is strongly decomposed by long heating.

*Management of gold baths.*—It is advisable to keep the content of gold in the baths prepared according to the different formulæ as constant as possible, which is best effected by the use of fine gold anodes. Insoluble platinum anodes are better liked in gilding than for all other electro-plating processes, partly because they are cheaper, and partly because they are recommended in most books on the subject. However, a bath which has become low in gold does not yield a beautiful gold color, and has to be frequently strengthened by the addition of chloride of gold, the preparation of which consumes time and causes expense, so that the use of gold anodes is the cheapest in the end.

The use of steel anodes for cold and warm cyanide gold baths, advocated by some, cannot be recommended. Every gilder knows from experience that, when the enamel of the vats containing the gold baths becomes defective, the baths in a short time fail. The reason for this is simply that the iron on the defective places of the vat decomposes the gold bath, metallic gold being separated. Iron, in this respect, acts like zinc, which, in a still shorter time, precipitates metallic gold from gold baths. Now, when iron anodes remain suspended in the baths, a separation of gold takes place, while a quantity of iron equivalent to the separated gold is dissolved, and, in the form of ferric oxide, falls to the bottom of the vat.

In hot gold baths this separation of gold proceeds still more rapidly and the content of potassium cyanide in the bath is

destroyed, yellow prussiate of potash being formed. The argument made in favor of the use of steel anodes, that the old practitioners often added intentionally yellow prussiate of potash to their baths to heighten the gold tone, is fallacious. A plater who works with gold baths prepared with yellow prussiate of potash cannot expect to replace the gold by the solution of the gold anodes, and when working with gold cyanide and potassium cyanide baths there is no inducement for gradually changing the bath into a yellow prussiate of potash bath by the use of steel anodes.

According to one statement, a hot gold bath with steel anodes showed, after being electrolyzed for 70 hours, scarcely a trace of iron. To ascertain the correctness of this statement by an experiment, a gold bath prepared according to formula IV., was electrolyzed at  $158^{\circ}$  F., with a blue annealed steel anode weighing 12.092 grammes. During the first two hours only a moderate yellow-reddish bloom of iron salt was perceptible on the anode, which became detached from the latter and fell to the bottom of the beaker. The bloom, however, became gradually heavier, the bottom of the beaker was covered with a precipitate of a yellow brown color, the previously colorless bath acquired a yellow color, and after electrolyzing for five hours, the blue color of the anode had largely disappeared. The anode weighed now 11.822 grammes, and had consequently lost 2.2 per cent. After again suspending it in the bath it was more rapidly attacked in consequence of the destruction of the blue annealing color which retarded corrosion. After five more hours the anode weighed 11.105 grammes, the loss being therefore 8.16 per cent. The bath now showed a deep yellow color, and the precipitate on the bottom of the beaker had increased, while small, lighter flakes of ferric hydrate spun around in the bath and attached themselves to the anode. Electrolysis was now discontinued, since the last mentioned phenomena proved the uselessness of steel anodes for the reasons given under "Deposition of Nickel and Cobalt."

As regards the advantage claimed for the use of steel anodes



that a large anode surface corresponding to the object surface can be rendered effective without taxing too severely the pocket-book of the gilder, it may be said that the same object can in a more rational manner be attained by employing carbon anodes which, to prevent contamination of the bath by particles of carbon, are placed in linen bags. Crosses and balls of unusually large dimensions for church towers have frequently been gilded in Dr. Geo. Langbein & Co.'s establishment, for which a large anode surface was required in order to obtain a uniformly heavy deposit, and in such cases carbon anodes of the best quality of retort graphite were used. These anodes, to be sure, become saturated with gold bath, and for that reason cannot be used for other baths. When not required for some time, they are kept in a vessel filled with clean water, and the latter is added to the bath to replace that lost by evaporation.

The employment of anodes of platinum strips or platinum wire may, perhaps, be advocated for coloring the deposit, *i. e.*, for the purpose of obtaining certain tones of color when gilding in the hot bath. By allowing the platinum anode to dip only slightly in the bath a pale gilding is obtained, because the current thereby becomes weaker; by immersing the anode deeper the color becomes more yellow, and by immersing it entirely the tone becomes more reddish. However, instead of producing these effects of the current-strength by the anode, which requires the constant presence of the operator, it is better to obtain the coloration by means of the resistance board. By placing the switch upon "strong" a reddish gold tone is obtained, and by placing it upon "weak" a paler gold tone, while the beautiful gold yellow lies in the middle between the two extremes. However, since even with the use of gold anodes the content of gold in the bath is not entirely restored, the bath has after some time to be strengthened, which is effected by a solution of fulminating gold or chloride of gold in potassium cyanide, according to the composition of the bath.

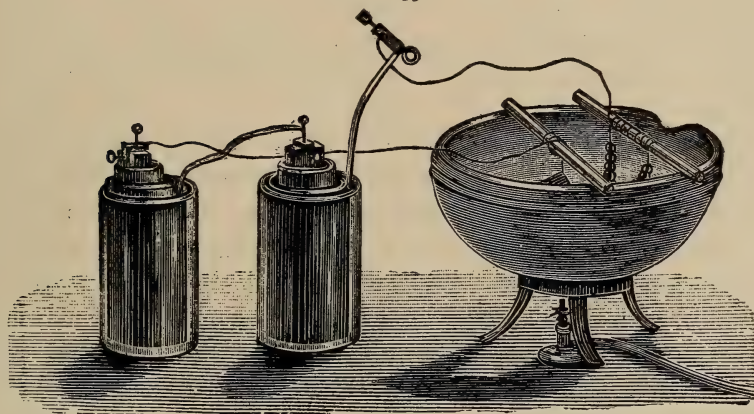
The excess of potassium cyanide must not be too large,

otherwise the gilding will be pale; but, on the other hand, it must not be too small, since in this case quite a strong current would have to be used to effect a normal deposition of gold, which, besides, would not be dense and homogeneous.

As in the silvering baths, the excess of potassium cyanide in the gold baths is also partially converted into potassium carbonate by the action of the air, the heat, etc., and it is, therefore, advisable from time to time to add a small quantity of potassium cyanide.

Gold baths for cold gilding are kept in vats of stoneware or enameled iron, or small baths in glass vats, which, to protect

FIG. 135.



them against breaking, are placed in a wooden box. Baths for hot gilding require enameled iron vats in which they can be heated by a direct fire, or better, by placing in hot water (water bath), or by steam. For small gold baths for hot gilding, a porcelain dish resting upon a short-legged iron tripod may be used, (Fig. 135.) Beneath the iron tripod is a gas burner supplied with gas by means of a flexible India-rubber tube connected to an ordinary gas burner. Across the porcelain dish are placed two glass rods, around which the pole-wires are wrapped. In heating larger baths in enameled vats over a

direct fire it may happen that on the places most exposed to the heat the enamel may blister and peel off; it is, therefore, better to heat the baths in a water or steam bath. For this purpose have made a box of stout iron or zinc sheet about  $\frac{3}{4}$  inch wider and longer, and about 4 inches deeper than the enameled vat containing the gold bath. To keep the level of the water constant, the box is to be provided with a water inlet and overflow pipe. In this box place the vat so that its edges rest upon those of the box, and make the joints tight with tow. The water-bath is then heated over a gas flame or upon a hearth, the water lost by evaporation being constantly replaced, so that the enameled vat is always to half its height surrounded by hot water. For heating by steam the arrangement is the same, only a valve for the introduction, and a pipe for the discharge, of steam, are substituted for the water inlet and overflow pipe.

*Execution of gold plating.*—Most suitable current density, 0.15 to 0.2 ampère. Like all other electro-plating operations, it is advisable to effect gold-plating with an external source of current, that is, to use a battery or other source of current separated from the bath, and to couple the apparatuses as previously described and illustrated by Figs. 54 and 55.

To be sure, there are still gilders who gild without a battery or separate external source of current and obtain good results, the process being, as a rule, employed only in gilding small articles. The apparatus used for this purpose consists of a glass vessel containing the gold solution compounded with a large excess of potassium cyanide and a porous clay cell filled with very dilute sulphuric acid or common salt solution, which is placed in the glass vessel. Care should be taken to have the fluids in both vessels at the same level. Immerse in the clay cell an amalgamated zinc cylinder or zinc plate, to which a copper wire is soldered. Outside the cell this copper wire is bent downwards, and the article to be gilded, which dips in the gold solution, is fastened to it. In working with this apparatus there is always a loss of gold, since the gold solution penetrates

through the porous cell, and on coming in contact with the zinc is reduced by it, the gold being separated as black powder upon the zinc. In cleaning the apparatus this black slime has to be carefully collected and worked for fine gold.

For the sake of greater solidity, only articles of silver and copper and its alloys should be directly gilded, while all other metals are best first brassed or coppered. Cleaning from grease and pickling is done in the same manner, as described on page 169. The preparation of the articles for gilding differs from that for silvering only in that the surfaces which later on are to appear with high lustre are not artificially roughened with emery, pumice, or by pickling, because, on the one hand, the gold deposit seldom needs to be made extravagantly heavy, and the rough surface formed would require more laborious polishing with the burnishers; and, on the other, the gold deposits adhere quite well to highly-polished surfaces, provided the current strength is correctly regulated, and the bath accurately composed according to one of the formulæ given. Quicking the articles before gilding, which is recommended by some authors, is not necessary.

The current-strength must, under no circumstances, be so great that a decomposition of water and consequent evolution of hydrogen on the objects takes place, since otherwise the gold would not deposit in a reguline and coherent form, but as a brown powder. By regulating the current-strength so that it just suffices for the decomposition of the bath, and avoiding a considerable surplus, a very dense and uniform deposit is formed; and by allowing the object to remain long enough in the bath, a beautiful, matt gold deposit can be obtained in all the baths prepared according to the formulæ given. It may, however, be mentioned that this mode of matt gilding is the most expensive, since it requires a very heavy deposit, and it will, therefore, be better to matten the surface previous to gilding, according to a process to be described later on.

For gilding with cold baths two freshly filled Bunsen elements coupled for tension suffice in almost all cases; while



for hot baths one element is, as a rule, sufficient, if the anode surface is not too small. The more electro-positive the metal to be gilded is, the weaker the current can and must be.

Though gold solutions are good conductors and, therefore, the portions of the articles which do not hang directly opposite the anodes gild well, for the solid plating of larger objects it is recommended to frequently change their positions except when they are entirely surrounded by anodes.

The inner surfaces of *hollow-ware*, such as drinking-cups, milk pitchers, etc., are best plated after freeing them from grease and pickling, by filling the vessel with the gold bath and suspending a current-carrying gold anode in the centre of the vessel, while the outer surface of the latter is brought in contact with the negative conducting wire. The lips of vessels are plated by placing upon them a cloth rag saturated with the gold bath and covering the rag with the gold anode.

For gold-plating in the cold bath the process is as follows: The objects, thoroughly freed from grease and pickled (and if of iron, zinc, tin, Britannia, etc., previously coppered), are suspended in the bath by copper wires, where they remain with a weak current until in about 8 or 10 minutes they appear uniformly plated. At this stage they are taken from the bath, rinsed in a pot filled with water, the latter, after having been used for some time, is added to the bath to replace the water lost by evaporation. The articles are finally brushed with a fine brass scratch-brush and tartar solution, thoroughly rinsed, again freed from grease by brushing with lime-paste and then returned to the bath, where they remain until they have acquired a deposit of sufficient thickness.

If it is intended to give them a very heavy deposit, it is advisable to scratch-brush them several times with the use of tartar or its solution. For gold-plating by weight the same plan as given for silver-plating (p. 311) is pursued.

For gold-plating with the hot bath the operations are the same, with the exception that a weaker current is introduced into the bath and the time of the plating process shortened. Frequent

scratch-brushing also increases the solidity of the deposit and prevents its prematurely turning to a dead brown-black. Since in hot plating more gold than intended is readily deposited, it is especially advisable to place a resistance board in the circuit, as otherwise the operator must remain standing alongside of the bath and regulate the effect of the current by immersing the anodes more or less.

With a somewhat considerable excess of potassium cyanide, and if the objects to be plated are not rapidly brought in contact with the current-carrying object rod, hot gold baths cause the solution of some metal. Therefore, when silver or silver-plated objects are constantly plated in them they yield a somewhat greenish gilding in consequence of the absorption of silver, or a reddish gilding due to the absorption of copper, if copper or coppered articles are constantly plated in them. Hence, for the production of such green or reddish color, gold-plating baths which have thus become argentiferous or cupriferous may be advantageously used. In order to obtain a deposit of green or red gold with fresh baths, the tone-giving addition of metal must be artificially effected, as will immediately be seen.

If, however, such extreme tones are not desired, the content of gold in the baths may be exhausted for preliminary plating with the use of platinum anodes, the sad gold color being then given in a freshly prepared bath.

The gold deposits are polished, in the same manner as silver deposits, with the burnisher and red ochre, and moistening with solution of soap, decoction of flaxseed, or soap-root, etc.

*Red gilding.*—In order to obtain a red gold with the formulæ given, a certain addition of copper cyanide dissolved in potassium cyanide has to be made to them. The quantity of such addition cannot be well expressed by figures, since the current-strength with which the articles are plated exerts considerable influence. It is best to triturate the copper cyanide in a mortar to a paste with water, and add of this paste to a moderately concentrated potassium cyanide solution as long as copper

cyanide is dissolved. Of this copper solution add, gradually and in not too large portions, to the gold solution until, with the current-strength used, the gold deposit shows the desired red tone. The absorption of copper by the bath may also be effected by replacing the gold anodes by copper anodes and circulating the current (suspending a few gold anodes to the object rod). The direct addition of copper cyanide is, however, preferable.

For the determination of the content of copper required for the purpose of obtaining a beautiful red gold, a bath for hot gilding which contained 10.8 grains of gold per quart was compounded with a solution of copper cyanide in potassium cyanide with 1.08 grains content of copper. The tone of the gilding, which previously was pure yellow, immediately passed into a pale red gold. By the further addition of 1.08 grains of copper a fiery red gold tone was obtained, while a third addition of 1.08 grains of copper yielded a color more approaching that of copper than of gold. These experiments show that 20 per cent. of copper of the weight of gold contained in the bath seems to be the most suitable proportion for obtaining a beautiful red gold.

*Green gilding.*—To obtain greenish gilding, solution of cyanide or chloride of silver in potassium cyanide has to be added to the gold bath. It is not easy to prepare greenish gilding of a pleasing color, and to obtain it the current-strength must be accurately proportioned to the object surface, since with too weak a current silver predominates in the deposit, the gilding then turning out whitish, while too strong a current deposits too much gold in proportion to silver, the gilding becoming yellow, but not green.

*Rose-color gilding* may be obtained by the addition of suitable quantities of copper and silver solutions, but such coloration requires much attention and thought.

*Matt gilding.*—As previously mentioned, a beautiful matt gold deposit may be obtained by the use of any of the formulas given, and a current correctly regulated, and allowing

sufficient time for gilding. The heavy deposit of gold required for this process makes it, however, too expensive, and it is, therefore, advisable to produce matt gilding by previously matting the basis-surface, since then a thinner deposit of gold will answer very well. The process of graining has already been described on p. 326. Another method is to matt the first deposit with the scratch-brush, and then to give a second deposit of gold which also turns out matt upon the matted surface. However, the operation of matting with the scratch-brush requires considerable skill.

Articles may be readily matted with the use of the sand blast, after which they are quickly drawn through the bright-dipping bath, thoroughly rinsed, and brought into the gold bath.

In the chemical or electro-chemical way, matting is effected by one of the following methods:

For this purpose the mixture of 1 volume of saturated solution of bichromate of potash and 2 volumes of concentrated hydrochloric acid, mentioned on p. 165, may be used. Brass articles are allowed to remain several hours in the mixture, and are then quickly drawn through the bright-dipping bath. Copper alloys may also be successfully matted by suspending them as anodes in a mixture of 90 parts water and 10 parts sulphuric acid, and drawing the matted articles through the bright-dipping bath.

*Or*, they are matt-silvered and the gold is deposited upon the matted layer of silver. Articles gilded upon a matt silver basis, however, acquire before long an ugly appearance, since in an atmosphere containing sulphuretted hydrogen, the silver becomes black, even under the layer of gold, and shines through.

More advantageous is the process of providing the articles with a matt copper coating in the acid galvanoplastic bath. They are then drawn through a not too strong pickle, rinsed, and gilded. This process is used for the so-called French gilding, and yields a very sad, beautiful gilding. The articles consisting of zinc are first heavily coppered in a cyanide cop-



per bath, then matted in the acid copper bath (see "Galvanoplasty"), care being taken that the slinging wire is in contact with the object-rod, which conducts the current, before the coppered zinc object is suspended in the bath. This process of coppering of zinc in the acid copper bath is, however, quite a delicate operation, and it will frequently be noticed, even with apparently very heavy coppering in the cyanide copper bath, that in suspending the articles in the acid bath, brownish-black places appear on which, by contact of the acid bath with zinc, copper in a pulverulent form is deposited. When this is observed, the articles must be immediately taken from the bath, thoroughly scratch-brushed, and again thoroughly and heavily coppered in the cyanide copper bath, before replacing them in the acid copper bath. It may be recommended to provide the coppered zinc articles with a thick deposit of nickel, and then to copper them matt in the acid bath, the percentage of unsuccessful coppering being much smaller than without previous nickeling. The matt-coppered articles are rapidly drawn through the bright-dipping bath and then gilded, the bath prepared according to formula III., and heated to about 140° F., being very suitable for the purpose.

*Coloring of the gilding.*—It has been frequently mentioned that the most rational and simple process of giving certain tones of color to the gilding is by means of a stronger or weaker current. Many operators, however, cling to the old method of effecting the coloration by gilder's wax or brushing with certain mixtures, and for this reason this process, which is generally used for coloring fire-gilding, shall be briefly mentioned.

To impart to the gold-deposit a *redder* color, the gilding-wax is prepared with a greater content of copper, while for greenish gilding more zinc-salt is added. There are innumerable receipts for the preparation of gilding-wax, nearly every gilder having his own receipt, which he considers superior to all others. Only two formulæ which yield good results will here be given, one (I.) for *reddish* gilding and one (II.) for *greenish* gilding.

I. Wax 12 parts by weight, pulverized verdigris 8, pulverized sulphate of zinc 4, copper scales 4, borax 1, pulverized bloodstone 6, copperas 2.

II. Wax 12 parts by weight, pulverized verdigris 4, pulverized sulphate of zinc 8, copper scales 2, borax 1, pulverized bloodstone 6, copperas 2.

Gilder's wax is prepared as follows: Melt the wax in an iron kettle, add to the melted mass, whilst constantly stirring, the other ingredients, pulverized and intimately mixed, in small portions, and stir until cold, so that the powder cannot settle on the bottom or form lumps. Finally, mould the soft mass into sticks about  $\frac{1}{3}$  inch in diameter.

Gilder's wax is applied as follows: Coat the heated gilded articles uniformly with the wax and burn off over a charcoal fire, frequently turning the articles. After the wax flame is extinguished, plunge the articles into water, scratch-brush with wine-vinegar, dry in sawdust, and polish.

To give gilded articles a beautiful, rich appearance, the following process may also be used: Mix 3 parts by weight of pulverized alum, 6 of saltpetre, 3 of sulphate of zinc, and 3 of common salt, with sufficient water to form a thinly-fluid paste. Apply this paste as uniformly as possible to the articles by means of a brush, and after drying, heat the coating upon an iron plate until it turns black; then wash in water, scratch-brush with wine-vinegar, dry, and polish.

*According to a French receipt*, the same result is attained by mixing pulverized blue vitriol 3 parts by weight, verdigris 7, sal ammoniac 6, and saltpetre 6, with acetic acid 31; immersing the gilded articles in the mixture or applying the latter with a brush; then heating the objects upon a hot iron plate until they turn black, and, after cooling, pickling in concentrated sulphuric acid.

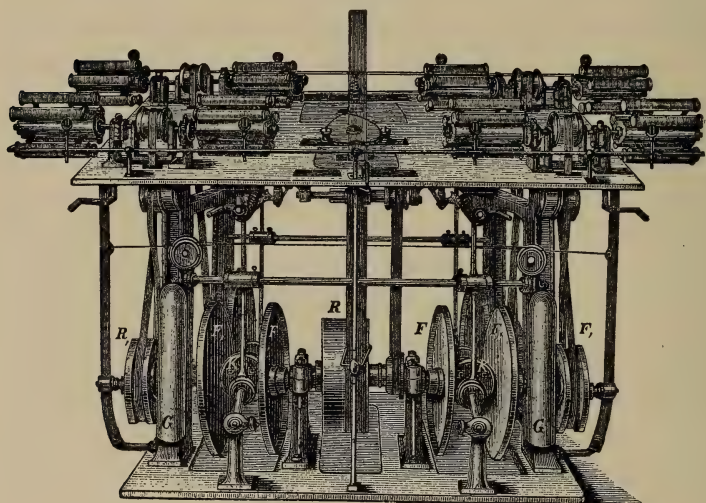
Some gilders *improve bad tones of gilding* by immersing the articles in dilute solution of nitrate of mercury until the gilding appears white. The mercury is then evaporated over a flame and the articles are scratch-brushed. Others apply a paste of

pulverized borax and water, heat until the borax melts, and then quickly immerse in dilute sulphuric acid.

*Incrustations with gold* are produced in the same manner as incrustations with silver described on p. 329.

*Gilding of metallic wire and gauze.*—Fine wire of gilded copper and brass is much used in the manufacture of metallic fringes and lace, for epaulettes and other purposes. The fine copper and brass wires being drawn through the draw-irons and wound upon spools by special machines, and hence not touched by the hands, freeing from grease may, as a rule, be

FIG. 136.



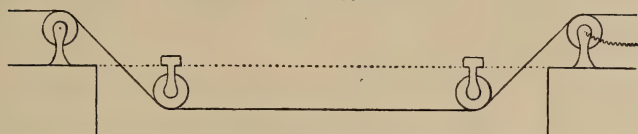
omitted. The first requisite for gilding is a good winding machine, which draws the wires through the gold bath and wash boxes, and further effects the winding of the wire upon spools. The principal demand made in the construction of such a machine is that by means of a simple manipulation, a great variation in the speed with which the wire or gauze passes through the gold bath can be obtained. This is necessary in order to be able to regulate the thickness of the gilding by the quicker or slower passage of the wire. A machine well adapted for

this purpose is that constructed by J. W. Spaeth and shown in Fig. 136.

The variation in the passage of the wire is attained by the two friction-pulleys  $F$ , which sit upon a common shaft with the driving-pulley,  $R$ , and transmit their velocity by means of the friction-pistons  $KK'$  to the friction-pulley  $F'$ , which is firmly connected to the belt-pulley  $R$  driving the spool spindle. Since by a simple device the pistons  $K$  and  $K'$  may be shifted, it is clear that the transmission of the number of revolutions from  $F$  to  $F'$  is dependent on the position of the friction pistons  $K$  and  $K'$ , and that the velocity will be the greater the shorter the distance they are from the centre of friction-pulleys  $F$  and  $F'$ . In order that the friction between  $F$ ,  $K$  and  $F'$  may always be sufficient for the transmission of the motion, even when the pistons are worn, four weights,  $G$ , are provided, which press the above-mentioned parts firmly against each other.

In front of each spool of this machine is inserted a small enameled iron vat which contains the gold bath, and is heated

FIG. 137.



by a gas flame to about  $167^{\circ}$  F. Between this bath and the winding machine is another small vat with hot water in which the gilded wire is rinsed.

The wire unwinds from a reel placed in front of the gold baths, run over a brass drum which is connected to the negative pole of the source of current and transmits the current to the wire. The dipping of the wire into the gold bath is effected by porcelain drums, which are secured to heavy pieces of lead placed across the vats, as shown in Fig. 137. The gilded wire being wound upon the spools of the winding machine, these spools are removed and thoroughly dried in



the drying chamber. The wire is then again reeled off on to a simple reel, in doing which it is best to pass it through between two soft pieces of leather to increase its lustre.

The most suitable gold bath is that prepared according to formula IV. The current-strength should be from 6 to 8 volts, which will produce a deposit of sufficient thickness even with the wire passing at the most rapid rate through the bath.

*Gilding by contact, by immersion, and by friction.*—For contact gilding by touching with zinc, formulæ I., II., IV. and V., may be used, IV. and V. being especially suitable if the addition of potassium cyanide is somewhat increased and the baths are sufficiently heated.

A contact gold bath prepared with yellow prussiate of potash according to the following formula also yields a good deposit.

VIII. Fine gold as chloride of gold 54 grains, yellow prussiate of potash 1 oz., potash 1 oz., common salt 1 oz., water 1 quart. The bath is prepared as given for formula III. For use, heat it to boiling.

Gilding by contact is done the same way as silvering by contact. The points of contact must be frequently changed, since in the gold bath intense stains are still more readily formed than in the silver bath.

For gilding by contact, Conrad Taucher recommends the following bath: Distilled water 10 quarts, sodium or potassium pyrophosphate 28 ozs., prussic acid  $4\frac{1}{2}$  drachms, crystallized chloride of gold  $13\frac{1}{2}$  drachms.

To prepare the bath, bring into a porcelain vessel or into a dish of enameled cast-iron 9 quarts of distilled \* water and add the 28 ozs. of pyrophosphate, stirring constantly with a glass rod. Then heat, and when solution is complete filter and set aside to cool.

While filtering the solution, the chloride of gold is prepared by bringing into a small glass flask  $5\frac{1}{2}$  drachms of fine rolled gold, 14 drachms of pure hydrochloric acid, and  $8\frac{1}{2}$  drachms

\* The use of distilled water is necessary, otherwise the lime salts contained in ordinary water would decompose a portion of the pyrophosphate.

of pure nitric acid. Apply a gentle heat to the bottom of the flask. In a few seconds vigorous effervescence accompanied by the evolution of orange-red vapors takes place, and the gold in a few minutes dissolves to a reddish-yellow fluid. To evaporate an excess of acids, which if brought into the bath might cause serious disturbances and even render the bath entirely useless, the flask is placed upon a piece of sheet-iron provided in the centre with a hole about 0.11 inch in diameter, and heated upon a stove or over a spirit lamp. When no more vapors escape and the solution has become thickly-fluid and has acquired an intense hyacinth-red color, remove the flask from the fire by means of wooden pincers and let cool. If properly prepared, the chloride of gold then congeals to an aggregate of saffron-yellow acicular crystals. If the color of the latter is red, too much heat has been applied. Such chloride of gold is very suitable for the preparation of electro-gilding baths, but if it is to be used for contact gilding a small quantity of the above-mentioned two acids has to be added, and, after heating, the mass has to be again evaporated.

It frequently happens that by careless manipulation the gold is "burnt," *i. e.*, the auric chloride is decomposed by too long continued heating, and is converted into insoluble aurous chloride, or even into pulverulent metallic gold. If such is the case, the treatment with the above-mentioned mixture of acids has to be repeated. The object of the perforated piece of sheet-iron, on which the flask is placed for the purpose of evaporating the solution, is to prevent the sides of the flask from being heated too strongly, as otherwise the thin layers of chloride of gold solution might be decomposed.

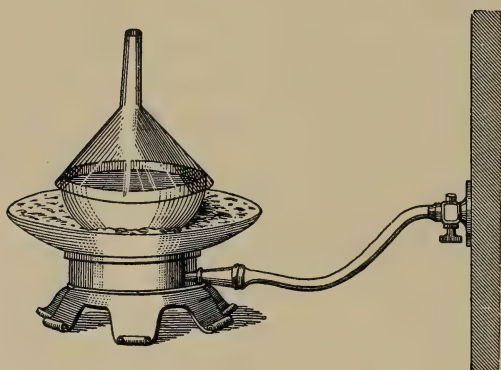
In practice porcelain capsules which are heated in a sand bath are generally used for dissolving gold. Fig. 138 shows such a capsule with glass funnel in a sand bath over a gas stove. The purpose of the glass funnel is to prevent any fluid from being thrown from the capsule at the moment of effervescence caused by the action of the acids upon the metal.

The cold crystallized chloride of gold in the flask or the cap-

sule is now dissolved in a small quantity of distilled water, solution being effected almost immediately. The solution is poured upon a filter of filtering paper in a glass funnel placed upon a clean bottle. A small piece of paper should be inserted between the funnel and the neck of the bottle, so that the air can escape from the latter and the fluid run off from the filter.

The object of filtering is to separate the small quantity of chloride of silver formed from the little silver which is present even in the purest commercial gold. To bring all the gold

FIG. 138.



into the bath, repeatedly wash the bottle and the filter with a small quantity of distilled water.

Now mix the cold solution of the pyrophosphate and that of the chloride of gold by pouring the latter gradually into the former and stirring with a glass rod. Then add the  $4\frac{1}{2}$  drachms of prussic acid and heat to the boiling point, when the bath is ready for use.

When mixed cold the bath has a yellow or yellow-greenish color, which disappears as the temperature rises. However, the fluid sometimes becomes currant-red or violet, which indicates that it contains too little prussic acid. This is remedied by adding drop by drop prussic acid until the fluid is entirely

discolored. Great care must, however, be exercised in adding the acid, as an excess of it renders the gilding pale.

By following the directions above given, the bath is very suitable for producing a beautiful yellow gilding on objects previously thoroughly cleansed. The articles should be passed through a very weak solution of mercurous nitrate, otherwise the gilding shades and becomes reddish. The articles to be gilded must be constantly moved in the bath. They are suspended to hooks or brought into the bath in dipping baskets of stoneware or brass.

Gilding is finished in a few seconds. The articles are then washed in clean water, dried in dry and warm sawdust, and if necessary, immediately polished.

By neglecting the precautionary measures given above, the gilding sometimes appears tarnished and dissimilar in tone. It is then colored or treated with the so-called matt for gilded articles.

For this purpose melt equal parts of the following salts in their water of crystallization at about  $212^{\circ}$  F.: Ferrous sulphate (green vitriol), zinc sulphate (white vitriol), alum, and salt-petre.

Thoroughly wet every portion of the defective gilding by turning the articles about in this mixture. Then place them in the centre of a cylindrical stove, in which the coal burns between the sides and a cylindrical grate, so that the entire heat radiates toward the empty space in the centre. The salts melt and then get into a fiery flux, the entire mass acquiring a dull earthen color. When on touching the articles with the moistened finger a slight hissing noise is heard, the temperature is sufficiently high and the articles are thrown into weak starch-water acidulated with sulphuric acid. The coating of salt dissolves immediately and the gilding presents a beautiful warm and uniform appearance. This operation can, of course, only be executed if the entire article has been gilded.

*Baths for gilding by dipping.* The following two formulas have stood the test:



I. Crystallized sodium pyrophosphate 2.82 ozs., 12 per cent. prussic acid 4.51 drachms, crystallized chloride of gold 1.12 drachms, water 1 quart. Heat the bath to the boiling point, and immerse the pickled objects of copper or its alloys, moving them constantly until gilded. Iron, steel, tin, and zinc should be previously coppered, coating the objects with mercury (quicking) being entirely superfluous.

All gold baths prepared with sodium pyrophosphate, when fresh, give rapid and beautiful results, but they have the disadvantage of rapidly decomposing, and consequently can seldom be completely exhausted. In this respect the following formula answers much better:

II. Crystallized sodium phosphate 2.82 drachms, chemically pure caustic potash 1.69 drachms, chloride of gold 0.56 drachm, 98 per cent. potassium cyanide 9.03 drachm, water 1 quart. Dissolve the sodium phosphate and caustic potash in  $\frac{3}{4}$  of the water, and the potassium cyanide and chloride of gold in the remaining  $\frac{1}{4}$ , and mix both solutions. Heat the solution to the boiling point. This bath can be almost entirely exhausted, it not being decomposed by keeping. Should the bath become weak, add about  $2\frac{3}{4}$  drachms of potassium cyanide, and use it for preliminary dipping until no more gold is reduced. To complete gilding, the objects subjected to such preliminary dipping are then immersed for a few seconds in a freshly-prepared bath of the composition given above.

The layer of gold formed is in all cases very thin, the amount of gold deposited corresponding to the quantity of basis-metal which has been dissolved.

III. One of the best directions for gilding without the use of the current is, according to the "Edelmetallindustrie," as follows: Prepare a solution of gold in aqua regia (2 parts hydrochloric acid and 1 part nitric acid). The solution of the gold is effected in a porcelain dish, best in a sand or water bath, whereby heavy brown acid vapors of hyponitrous acid are evolved. When all is dissolved allow the acid to evaporate until the fluid has acquired a deep brown color and no more

acid vapors arise. Then, after cooling, dilute the solution with water and keep it in a bottle for future use. Next dissolve in the bath  $6\frac{3}{4}$  drachms of potassa and  $11\frac{1}{4}$  drachms of sodium phosphate, and add enough gold solution that the bath contains about  $2\frac{1}{4}$  drachms of gold. To this bath, containing about 8 to 10 quarts of fluid, add carefully, with constant stirring,  $1\frac{3}{4}$  ozs. of potassium cyanide, and then let it thoroughly boil for some time. After cooling the bath to about  $176^{\circ}$  or  $158^{\circ}$  F., suspend the articles in it and keep the bath at this temperature. The bath only requires an occasional addition of gold solution (when the gilding becomes gray or dirty), or of potassium cyanide (when the gilding becomes foxy), and, with proper treatment, can be used for a long time.

*Gilding of porcelain, glass, etc.*—The pyrophosphate baths given above may be advantageously employed for gilding porcelain, glass, stoneware, etc., the process being as follows:

Neutral platinic chloride is intimately triturated with enough lavender oil to form a thin syrup. Of this preparation a scarcely perceptible film is applied by means of a small brush to the article to be ornamented. When dry, the article is heated in a muffle to a dark red heat. At this temperature the essential oil partially volatilizes, while another portion is decomposed, and reduces by its hydrogen the platinic chloride to metallic platinum, the result being a coating of metal of a finely polished appearance. When cold the article is immediately drawn through nitric acid, which does not attack the platinum, but removes any impurities which might make its surface dull. The article is then washed in a large quantity of water, wrapped with fine brass wire in such a manner that the wire touches the platinized places at many points, and is then brought into the gold bath. In a few minutes the platinum is coated with a beautiful smooth film of gold, which adheres well, and only requires rubbing with chamois.

By this method the expensive work of polishing is rendered unnecessary, which with articles having many depressed places is besides almost impossible. If the gilding is too red, add to

the bath a few drops of the double cyanide of potassium and silver.

*Gilding by friction.*—This process is variously termed *gilding with the rag, with the thumb, with the cork*. It is chiefly employed upon silver, though sometimes also upon brass and copper. The operation is as follows: Dissolve 1.12 to 1.69 drachms of chloride of gold in as little water as possible, to which has previously been added 0.56 drachm of saltpetre. Dip in this solution small linen rags, and, after allowing them to drain off, dry them in a dark place. These rags saturated with gold solution are then charred to tinder at not too great a heat, whereby the chloride of gold is reduced, partially to protochloride and partially to finely divided metallic gold. This tinder is then rubbed in a porcelain mortar to a fine uniform powder.

To gild with this powder, dip into it a charred cork moistened with vinegar or salt water and rub, with not too gentle a pressure, the surface of the article to be gilded, which must be previously cleansed from adhering grease. The thumb of the hand may be used in place of the cork, but in both cases care must be had not to moisten it too much, as otherwise the powder takes badly. After gilding, the surface may be carefully burnished.

For gilding by friction, a solution of chloride of gold in an excess of potassium cyanide may also be used, after thickening the solution to a paste by rubbing in whiting. The paste is applied to the previously zincked metals by means of a cork, a piece of leather, or a brush. Martin and Peyraud, the originators of this method, describe the operation as follows: Articles of other metals than zinc are placed in a bath consisting of concentrated solution of sal ammoniac, in which has been placed a quantity of granulated zinc. The articles are allowed to boil a few minutes, whereby they acquire a coating of zinc. For the preparation of the gilding composition, dissolve 11.28 drachms of chloride of gold in a like quantity of water, and add a solution of 2.11 ozs. of potassium cyanide in as little

water as possible (about 2.8 ozs.). Of this solution add so much to a mixture of 3.52 ozs. of fine whiting and 2.82 drachms of pulverized tartar that a paste is formed which can be readily applied with a brush to the article to be gilded. When the article is coated, heat it to between  $140^{\circ}$  and  $158^{\circ}$  F. After removing the dry paste by washing, the gilding appears and can be polished with the burnisher.

*Fire or mercury gilding.*—Before the introduction of electroplating, nearly all substantial gilding was effected by this process. However, the cost is much greater, the execution of the process presenting many difficulties, and besides the workman is constantly exposed to the very injurious mercurial vapors. The resulting gilding, however, is distinguished by great solidity.

The execution of fire gilding begins with the preparation of the amalgam of gold. For this purpose put a weighed quantity of fine gold in a crucible and heat to dull redness. The requisite proportion of mercury, 8 parts to 1 of gold, is now added, and the mixture is stirred with a slightly crooked iron rod, the heat being kept up until the gold is entirely dissolved by the mercury. Pour the amalgam into a small dish about 3 parts filled with water, and work about with the fingers under the water to squeeze out as much of the excess of mercury as possible. To facilitate this the dish is slightly inclined, to allow the superfluous mercury to flow from the mass, which soon acquires a pasty condition capable of receiving the impression of the fingers. Afterward squeeze the amalgam in a chamois leather bag, by which a further quantity of mercury is liberated. The amalgam, which remains after this final treatment, consists of about 33 parts of mercury and 67 parts of gold in 100 parts. The mercury which is pressed through the bag retains a good deal of gold, and is employed in preparing fresh batches of amalgam. It is important that the mercury employed should be pure.

To apply the amalgam, a solution of nitrate of mercury is employed which is prepared by dissolving in a glass flask 100



parts of mercury in 110 parts of nitric acid of specific gravity 1.33, gentle heat being employed to assist the chemical action. The red fumes given off must be allowed to escape into the chimney, since they are very deleterious when inhaled. When the mercury is all dissolved the solution is to be diluted with about 25 times its weight of distilled water, and bottled for use.

The pasty amalgam is spread with the blade of a knife upon a hard, flat stone. The article, after being well cleaned and scratch-brushed, is treated as follows: Take a small scratch-brush, formed of stout brass wire, dip in the solution of nitrate of mercury, then draw over the amalgam, pass the brush carefully over the surface to be gilded, repeatedly dipping the brush in the mercurial solution and drawing it over the amalgam until the entire surface is uniformly and sufficiently coated. Then rinse the article well, and dry. The next operation is the evaporation of the mercury. For this purpose a charcoal fire, resting upon a cast-iron plate, has been generally adopted, a simple hood of sheet-iron being the only means of protection from the injurious effects of the mercurial vapors. When the amalgamated article is rinsed and dried, it is exposed to the glowing charcoal, turned about and heated by degrees to the proper point, then it is withdrawn from the fire by means of long pincers or tongs. The article is then taken in the left hand, which should be protected with a leather glove, turned over the fire in every direction, and while the mercury is volatilizing the article should be struck with a long-haired brush to equalize the amalgam coating and force it upon such parts as may appear to require it. When the mercury has become entirely volatilized the gilding has a dull, greenish-yellow color. If any bare places are apparent, they are touched up with amalgam and the article is again submitted to the fire, care being taken to expel the mercury gradually. The article is then well scratch-brushed. When it is of a pale greenish color, heat it again to expel any remaining mercury, when it acquires the orange-yellow of fine gold. If required to be bright, it is burnished in the ordinary way. If the gild-

ing is to be dead, secure the article by means of iron wire to the end of an iron rod and coat it with a hot paste consisting of saltpetre, common salt, and alum; then expose the article to a bright fire, turning it in every direction until the coat of the mixture fuses and begins to run off; then remove the article from the fire and throw it in a wooden vat containing a large quantity of water. The coat of salts covering the article is immediately dissolved, and the gilding presents a beautiful dead appearance. To stand this process of deadening, the article must be well gilded, especially, as frequently happens, if the operation does not succeed the first time.

Red streaks are often observed on otherwise successful gilding. These streaks are caused by the iron wire which has been wrapped round the article. They disappear by plunging the article in dilute nitric acid, or, still better, in pure hydrochloric acid.

For the sake of completeness, a method of gilding which gives to some parts of the article a bright, and to others a matt, appearance may here be mentioned. It is a combination of fire-gilding with electro-deposition, the matt places being produced by the former operation and the bright places by the latter. The operation is as follows: The places which are to be matt are first gilded with amalgam, heated, scratch-brushed and raised. The entire article is then gilded with the assistance of the battery, no attention being paid to any gold depositing upon the surfaces already gilded. The entire surface is then carefully scratch-brushed, and the electro-gilded surfaces are next coated with a paste of flake-white, water and glue, and then with a thick paste of clay, the fire-gilded surfaces remaining free. The whole is then allowed to dry, when the fire-gilded surfaces are matted by being treated, as above described, with a hot paste of saltpetre, common salt and alum. The coatings of flake-white and clay are then dissolved by means of water acidulated with hydrochloric acid. The only purpose of these coatings is to prevent a too intense action of the heat upon the electro-gilded portions. The latter, if necessary, are

then again scratch-brushed, which must, however, be done with the greatest care to avoid injury to the matt portions. The article is finally polished.

The following process, however, is better and more convenient:

The surfaces which are to remain matt are first gilded and deadened, and then coated with varnish. When dry the article is pickled; the acid does not attack the varnished surfaces. The object is then brought into the electro-gilding bath, which also does not attack the varnish. When the desired shade of gold has been obtained, the article is taken from the bath and the varnish removed by means of benzine. The article is then washed in a warm potassium cyanide solution, next in boiling water, and finally dried. The matt gilding, no matter by which process it may have been produced, is only suitable for articles not exposed to friction, a slight touch with the fingers being sufficient to deprive it of its delicate lustre.

Old matt gilding may be improved by boiling with potash and washing in dilute sulphuric or nitric acid. This suffices for the removal of stains caused by grease, smoke or dust. If, however, the gilding is worn off, the article has to be scratch-brushed and regilt.

Du Fresne gives a method of gilding, which is also a combination of fire-gilding with electro-deposition. It is executed as follows:

The articles are galvanized with the assistance of the current, in a mercurial solution consisting of cyanide of mercury in potassium cyanide, with additions of carbonate and phosphate of soda, then gilded in an ordinary gilding bath, next again coated with mercury, then again gilded, and so on, until a deposit of sufficient thickness is obtained. The mercury is then evaporated over glowing coals, and the articles, after scratch-brushing, are burnished.

*According to another process*, the articles are gilded in a bath consisting of 98 per cent. potassium cyanide 1.2 ozs., cyanide of gold  $92\frac{1}{2}$  grains, cyanide of mercury  $92\frac{1}{2}$  grains, distilled

water 1 quart, a strong current being used. The articles being sufficiently gilded, the mercury is evaporated, the articles scratch-brushed and finally polished.

*Removing gold from gilded articles*—"Stripping."—Gilded articles of *iron* and *steel* are best stripped by treating them as anodes in a solution of from 2 to  $2\frac{3}{4}$  ozs. of 98 per cent. potassium cyanide in 1 quart of water, and suspending a copper plate greased with oil or tallow as the cathode. Gilded *silver-ware* is readily stripped by heating to ignition and then immersing in dilute sulphuric acid, whereby the layer of gold cracks off, the heating and subsequent immersion in dilute sulphuric acid being repeated until all the gold is removed. Before heating and immersing in dilute sulphuric acid, the articles may first be provided with a coating of a paste of sal ammoniac, flowers of sulphur, borax, and nitrate of potash, which is allowed to dry. On the bottom of the vessel containing the dilute sulphuric acid the gold will be found in laminæ and scales, which are boiled with pure sulphuric acid, washed, and finally dissolved in aqua regia, and made into chloride of gold or fulminating gold.

To strip articles of *silver*, *copper*, or *German silver* which will not bear heating, the solution of gold may be effected in a mixture of 1 lb. of fuming sulphuric acid, 2.64 ozs. of concentrated hydrochloric acid, and 1.3 ozs. of nitric acid of  $40^{\circ}$  B. Dip the articles in the warm acid mixture and observe the progressive action of the mixture by frequently removing the articles from it. The articles to be treated must be perfectly dry before immersing in the acid mixture, and care must be had to preserve the latter from dilution with water in order to prevent the acids from acting upon the basis-metal.

*Determination of genuine gilding*.—Objects apparently gilded are rubbed upon the touchstone, and the streak obtained is treated with pure nitric acid of 1.30 to 1.35 specific gravity. The metal contained in the streak thereby dissolves, and as far as it is not gold disappears, while the gold remains behind. The stone should be thoroughly cleansed before each operation,



and the streak should be made not with an edge or a corner of the object to be tested, but with a broader surface. If no gold remains upon the stone, but there is, nevertheless, a suspicion of the article being slightly gilded, proceed with small articles as follows: Take hold of the article with a pair of tweezers, and after washing it first with alcohol, and then with ether, and drying upon blotting paper, pour over it in a test glass, cleansed with alcohol or ether, according to the weight of the article, 0.084 to 5.64 drachms of nitric acid of 1.30 specific gravity free from chlorine. The article will be immediately dissolved, and if it has been gilded never so slightly, perceptible gold spangles will remain upon the bottom of the glass.

#### *Examination of Gold Baths.*

The determination of free potassium cyanide and of the potassium carbonate which is formed, is effected in the same manner as given under "Examination of copper baths and of silver baths."

The determination of the gold is effected by the electrolytic method. With baths poor in gold, 50 cubic centimeters are used for electrolysis, and with baths rich in gold, 25 cubic centimeters. After diluting with water to within 1 centimeter of the rim of the platinum dish, the liquid is electrolyzed for about three hours with a current-density  $ND\ 100 = 0.057$  ampère, the complete separation of the gold being recognized by a platinum strip suspended over the rim of the dish and dipping into the fluid showing in fifteen minutes no trace of a separation of gold.

The dish is then washed, rinsed with alcohol, and dried at  $212^{\circ}$  F. To obtain the content of gold in grammes per liter of bath, multiply the weight of the precipitate by 20, when 50 cubic centimeters, or by 40, when 25 cubic centimeters, of the bath have been used.

The content of gold in the baths declines constantly, especially with the use of platinum and carbon anodes. For strengthening the baths neutral gold chloride dissolved in potassium

cyanide is used, 2 grammes neutral gold chloride and 1.4 grammes 99 per cent. potassium cyanide dissolved in a small quantity of water or directly in the bath, being required for every gramme of gold deficit in the baths.

The determination of gold described above is suitable only for baths prepared with potassium cyanide, which contain the gold in the form of potassium gold cyanide. The determination of gold in baths prepared with yellow prussiate of potash is more difficult and should be made by a skilled analyst.

*Recovery of gold from gold baths, etc.*—To recover the gold from old cyanide gilding baths, evaporate the baths to dryness, mix the residue with litharge, and fuse the mixture. The gold is contained in the lead button thus obtained. The latter is then dissolved in nitric acid, whereby the gold remains behind in the form of spangles. These spangles are filtered off and dissolved in aqua regia.

The following method is used for the recovery of gold by the *wet process*: The bath containing gold, silver and copper is acidulated with hydrochloric acid, which causes a disengagement of hydrocyanic acid. This gas is extremely poisonous, for which reason the operation should be carried on in the open air, or where there is a good draught or ventilation to carry off the fumes. A precipitate consisting of the cyanides of gold and copper and chloride of silver is formed. This is well washed and boiled in aqua regia, which dissolves the gold and copper as chlorides, leaving the chloride of silver behind. The solution containing the gold and copper is evaporated nearly to dryness in order to remove the excess of acid, the residue is dissolved in a small quantity of water, and the gold precipitated therefrom as a brown metallic powder by the addition of sulphate of iron (copperas). The copper remains in solution.

Finely divided zinc—so-called zinc-dust—is an excellent agent for the precipitation of gold in a pulverulent form from cyanide gilding baths. By adding zinc-dust to an exhausted cyanide gilding bath, and thoroughly shaking or stirring it from time to time, all the gold is precipitated in two or three

days. The quantity of zinc required for precipitation depends of course on the quantity of gold present, but generally speaking,  $\frac{1}{2}$  lb., or at the utmost 1 lb., of zinc-dust will be required for 100 quarts of exhausted gilding bath.

The pulverulent gold obtained is washed, treated first with hydrochloric acid to remove adhering zinc-dust, and next with nitric acid to free it from silver and copper.

From the *acid mixtures* serving for matt pickling gold, or for stripping, the gold is precipitated by solution of sulphate of iron (copperas) added in excess. The gold present is precipitated as a brown powder mixed with ferric oxide. This powder is filtered off and treated in a porcelain dish with hot hydrochloric acid, which dissolves the iron. The gold which remains behind is then filtered off, and, after washing, dissolved in aqua regia in order to work the solution into fulminating gold or neutral chloride of gold.

## CHAPTER XI.

### DEPOSITION OF PLATINUM AND PALLADIUM.

#### I DEPOSITION OF PLATINUM.

*Properties of platinum.*—Pure platinum is white with a grayish tinge. It is as soft as copper, malleable and very ductile. At a white heat it can be welded, but is fusible only with the oxyhydrogen blowpipe or by the electric current. Its specific gravity is 21.4.

Air has no oxidizing action upon platinum. It is scarcely acted upon by any single acid; prolonged boiling with concentrated sulphuric acid appears to dissolve the metal slowly. The best solvent for it is aqua regia, which forms the tetrachloride,  $\text{PtCl}_4$ . Chlorine, bromine, sulphur and phosphorus combine directly with platinum, and fusing saltpetre and caustic alkali attack it.

Besides, in the malleable and fused state, platinum may be obtained as a very finely divided powder, the so-called *platinum black*, which is precipitated with zinc from dilute solution of platinum chloride acidulated with hydrochloric acid.

*Platinum baths.*—In view of the valuable properties of platinum of oxidizing only under certain difficult conditions, of possessing an agreeable white color, and of taking a fine polish, it seems strange that greater attention has not been paid to the electro-deposition of this metal than is actually the case. The reason for this may perhaps be found in the fact that the baths formerly employed for experiments possessed serious defects, causing the operator many difficulties, and besides allowed only of the production of thin deposits. Giving due consideration to the requirements of the process of electro-deposition of platinum, and with the use of a suitable bath, deposits of platinum of



a certain thickness can be readily produced, and necessary conditions will be described under "Treatment of platinum baths."

The platinum baths formerly proposed did not yield satisfactory results, because the content of platinum was too small in some of them, while with others dense deposits could not be obtained. A more recent formula by Boettger, however, gives quite a good bath. A moderately dilute boiling hot solution of sodium citrate is added to platoso-ammonium chloride until an excess of the latter no longer dissolves, even after continued boiling. The following proportions have been found very suitable: Dissolve  $17\frac{1}{2}$  ozs. of citric acid in 2 quarts of water, and neutralize with caustic soda. To the boiling solution add, whilst constantly stirring, the platoso-ammonium chloride freshly precipitated from 2.64 ozs. of chloride of platinum, heat until solution is complete, allow to cool, and dilute with water to 5 quarts. To decrease the resistance of the bath, 0.7 or 0.8 oz. of sal ammoniac may be added; a larger addition, however, will cause the separation of dark-colored platinum.

The platoso-ammonium chloride is prepared by adding to a concentrated solution of chloride of platinum concentrated solution of sal ammoniac until a yellow precipitate is no longer formed on adding a further drop of sal ammoniac. The precipitate is filtered off and brought into the boiling solution of sodium citrate. This bath works very uniformly if the content of platinum is from time to time replenished.

"The Bright Platinum Plating Company," of London, has patented the following composition of a platinum bath: Chloride of platinum 0.98 oz., sodium phosphate  $19\frac{3}{4}$  ozs., ammonium phosphate 3.95 ozs., sodium chloride 0.98 oz., and borax 0.35 oz., are dissolved, with the aid of heat, in 6 to 8 quarts of water, and the solution is boiled for 10 hours, the water lost by evaporation being constantly replaced. The results obtained with this bath were not much better than with Böttger's.

Dr. W. H. Wahl gives the following directions for preparing platinum baths:\*

\* Journal of the Franklin Institute, July, 1890.

*Alkaline platinate bath.*—Platinic hydrate, 2 ozs.; caustic potassa (or soda), 8 ozs.; distilled water, 1 gallon.

Dissolve one-half of the caustic potassa in a quart of distilled water, add to this the platinic hydrate in small quantity at a time, facilitating solution by stirring with a glass rod. When solution is effected, stir in the other half of alkali dissolved in a quart of water; then dilute with enough distilled water to form one gallon of solution. To hasten solution, the caustic alkali may be gently heated, but this is not necessary, as the platinic hydrate dissolves very freely. This solution should be worked with a current of about two volts, and will yield metal of an almost silvery whiteness upon polished surfaces of copper and brass, and quite freely. There should be slight, if any, perceptible evolution of hydrogen at the cathode, but a liberal evolution of oxygen at the anode. An addition of a small proportion of acetic acid to this bath improves its operation where a heavy deposit is desired. The anode must be of platinum or carbon, and owing to the readiness with which the metal is deposited, an excess of anode-surface is to be avoided. Articles of steel, nickel, tin, zinc, or German silver will be coated with black and more or less non-adherent platinum; but by giving objects of these metals a preliminary thin electro-deposit of copper in the hot cyanide bath they may be electro-platinized in the alkaline platinate bath equally as well as copper. The bath may be worked hot or cold, but it is recommended to work it at a temperature not exceeding 100° F. It may be diluted to one-half the strength indicated in the formula and still yield excellent results. The surface of the objects should be highly polished by buffing or otherwise prior to their introduction into the bath, if the resulting deposit is designed to be brilliant.

The deposition of platinum takes place promptly. In five minutes a sufficiently heavy coating will be obtained for most purposes. The deposited metal is so soft, however, that it requires to be buffed very lightly. A heavier deposit will appear gray in color, but will accept the characteristic lustre of platinum beneath the burnisher.

An *oxalate solution* is prepared by dissolving 1 oz. of platinic hydrate in 4 ozs. of oxalic acid and diluting the solution to the volume of one gallon with distilled water. The solution should be kept acidified by the occasional addition of some oxalic acid. The simplest plan of using this bath, which requires no attention to proportions, is simply to work with a saturated solution of the oxalate, keeping an undissolved excess always present at the bottom of the vessel. An addition of a small quantity of oxalic acid now and then will be found advantageous. The double salts of oxalic acid with platinum and the alkalies may be formed by saturating the binoxalate of the desired alkali with platinic hydrate and maintaining the bath in normal metallic strength by the presence of an undissolved residuum of platinous oxalate.

The double oxalates are not so soluble in water as the simple salt. The oxalate baths, both of single and double salts, may be worked cold or hot (though not to exceed  $150^{\circ}$  F.) with a current of comparatively low pressure. The metal will deposit bright, reguline and adherent on copper and brass. Other metallic objects must receive a preliminary coppering as above. The deposited metal is dense, with a steely appearance, and can be obtained of any desired thickness.

The deposit obtained in the oxalate bath is sensibly harder than that from the alkaline platinate bath, and will bear buffing tolerably well.

The *phosphate bath* may be prepared by the following formula:

Phosphoric acid, syrupy (specific gravity 1.7), 8 ozs., platinic hydrate 1 to  $1\frac{1}{2}$  ozs., distilled water 1 gallon.

The acid should be moderately diluted with distilled water and the solution of the hydrate effected at the boiling temperature. Water should be added cautiously from time to time to supply that lost by evaporation. When solution has taken place, the same should be diluted with sufficient water to make the volume 1 gallon. The solution may be worked cold or heated to  $100^{\circ}$  F., and with a current much stronger than that

required for the platينات and oxalates. The ammonio (and sodio) platinic phosphates may be formed from the simple phosphate by carefully neutralizing the solution of the phosphate with ammonia (or soda); then adding an excess of phosphoric acid, or enough to dissolve the precipitate formed, and an additional quantity to insure a moderate amount of free phosphoric acid in the bath. The phosphate baths will be maintained of normal strength by additions of platinic hydrate, the solutions of which will need to be assisted by heating the bath, preferably at the close of each day's work. The metal yielded by the electrolysis of these phosphate solutions is brilliant and adherent. It has the same steely appearance as that exhibited by the oxalate solutions, but to a less pronounced degree. The physical properties of the deposited metal are in other respects like those described in connection with that obtained from the oxalate baths.

*Management of platinum baths.* Copper and brass may be directly plated with platinum, but iron, steel and other metals are first to be coppered, otherwise they would soon decompose the platinum bath, independent of the fact that an unexceptionable deposit cannot be produced upon them without the cementing intermediary layer of copper.

Platinum baths must be used hot, and even then require a current of 5 to 6 volts, and hence, in plating with a battery at least three, or better four, Bunsen elements must be coupled, one after the other, for tension. An abundant evolution of gas must appear on the objects and anodes. The anode-surface (platinum anodes) must not be too small, and should be only at a few centimeters distance from the objects. Since the platinum anodes do not dissolve, the content of platinum in the bath decreases constantly, and the bath must from time to time be strengthened. For this purpose, the bath, prepared according to Böetger's formula, is heated in a porcelain dish or enameled vessel to the boiling point, a small quantity of fresh solution of sodium citrate is added and platoso-ammonium chloride introduced so long as solution takes place. A concentrated



solution of platoso-ammonium chloride in sodium citrate (so-called platinum essence) may be kept on hand and a small quantity of it be at intervals added to the bath. Baths prepared according to the English method are strengthened by the addition of platinum chloride.

*Execution of platinum-plating.*—The objects thoroughly freed from grease and, if necessary, coppered, are suspended in the bath heated to between  $176^{\circ}$  and  $194^{\circ}$  F., and this temperature must be maintained during the entire operation. The current should be of sufficient strength and the anodes placed so close to the objects that a liberal evolution of gas appears on them. For plating large objects, it is recommended to go round them, at a distance of 0.31 to 0.39 inch, with a hand-anode of platinum sheet, which should not be too small and should be connected to the anode-rod. When the current has vigorously acted for 8 to 10 minutes, the objects are taken from the bath, dried, and polished. However, for the production of heavy deposits—for instance, upon points of lightning-rods—the deposit is vigorously brushed with a steel-wire scratch-brush or fine pumice-powder. The objects are then once more freed from grease and returned for 10 or 15 minutes longer to the bath to receive a further deposit of platinum with a weaker current, which must, however, be strong enough to cause the escape of an abundance of gas-bubbles. The objects are then taken out, and after immersion in hot water, dried in sawdust. The deposit is then well burnished, first with the steel tool and finally with the stone, whereby the gray tone disappears and the deposit shows the color and lustre of massive platinum sheet. Points of lightning-rods platinized in this manner were without flaw after an exposure to atmospheric influences for more than six years.

*Platinizing of glass.*—Glass may be platinized by means of the galvanic current as follows: Dissolve 14 drachms of platinic hydrate in  $17\frac{1}{2}$  ozs. of a 10 per cent. solution of caustic soda or potash. Add to the solution  $17\frac{1}{2}$  ozs. more of the alkali solution and dilute with water to 2 quarts. The temperature

of the bath should not exceed  $100^{\circ}$  F., and the strength of the current should be two volts.

*Platinizing by contact.*—Though a thick deposit cannot be produced by the contact-process, Fehling's directions may here be mentioned as suitable for giving a thin coat of platinum to fancy articles. He recommends a solution of 5.64 drachms of chloride of platinum and 7 ozs of common salt in 1 quart of water, which is made alkaline by the addition of a small quantity of soda lye, and for use heated to the boiling point.

If larger articles are to be platinized by contact, free them from grease, and after pickling, and if necessary, coppering, wrap them round with zinc wire, or place them upon a bright zinc sheet, and introduce them into the heated bath. All the remaining manipulations are the same as in other contact processes.

*Recovery of platinum from platinum solutions.*—From not too large baths, precipitation of the platinum with sulphuretted hydrogen is the most suitable method, and preferable to evaporating and reducing the metal from the residue. The process is as follows: Acidulate the platinum solution with hydrochloric acid, and, after warming it, conduct sulphuretted hydrogen into it. The metal (together with any copper present) precipitates as sulphide of platinum. The precipitate is filtered off, dried, and ignited in the air, whereby metallic platinum remains behind. From larger baths the platinum may be precipitated by suspending bright sheets of iron in the acidulated bath. In both cases the precipitated platinum is treated with dilute nitric acid in order to dissolve any copper present. After filtering off and washing the pure platinum, dissolve it in aqua regia. The solution is then evaporated to dryness in the water bath, and the chloride of platinum thus obtained may be used in making a fresh bath.

## 2 DEPOSITION OF PALLADIUM.

*Properties of palladium.*—Palladium, when compact, has a white color and possesses a lustre almost equal to that of silver.

Its specific gravity is about 12.0; it is malleable and ductile, and may be fused at a white heat. In the oxy-hydrogen flame it is volatilized, forming a green vapor. It is less permanent in the air than platinum. It is dissolved by nitric acid; it is scarcely attacked, however, by hydrochloric or sulphuric acid. Hydriodic acid and free iodine coat it with the black palladium iodide.

On account of the high price of its salts, palladium has been but little used for electro-plating purposes; nor for, the same reason, is it likely to be more extensively employed in the future.

According to M. Bertrand, the most suitable bath consists of a neutral solution of the double chloride of palladium and ammonium, which is readily decomposed by 3 Bunsen elements coupled one behind the other (therefore about 5.4 volts). A sheet of palladium is used as anode.

A solution of palladium cyanide in potassium cyanide does not yield as good results as the above bath.

Palladium is entirely constant in the air, and in color closely resembles silver. It possesses further the property of not being blackened by sulphuretted hydrogen, and for this reason it is sometimes employed for coating silver-plated metallic articles.

Palladium has also of recent years been employed for plating watch movements. According to M. Pilet, 4 milligrammes (about  $\frac{1}{17}$  grain) of palladium are sufficient to coat the works of an ordinary sized watch. M. Pilet recommends the following bath: Water 2 quarts, chloride of palladium  $5\frac{1}{2}$  drachms, phosphate of ammonia  $3\frac{1}{2}$  ozs., phosphate of soda  $17\frac{1}{2}$  ozs., benzoic acid  $2\frac{3}{4}$  drachms.

*Deposits of iridium and rhodium* have recently been produced from baths similar in composition to those mentioned under palladium. But as these metals would be used for plating purposes only in isolated cases, it is not necessary to enter into details.

## CHAPTER XII.

### DEPOSITION OF TIN, ZINC, LEAD, AND IRON.

#### I. DEPOSITION OF TIN.

*Properties of tin.*—Tin is a white, highly lustrous metal. It possesses but little tenacity, but has a high degree of malleability, and tin-foil may be obtained in leaves less than  $\frac{1}{50}$ th of a millimetre in thickness. Tin melts at about  $445^{\circ}$  F. and evaporates at a high temperature. The fused metal shows great tendency to crystallize on congealing. By treating the surface of melted tin with a dilute acid, the crystalline structure appears as designs (*moiré métallique*), resembling the ice-flowers on frosted windows.

Tin remains quite constant even in moist air, and resists the influence of an atmosphere containing sulphuretted hydrogen. Strong hydrochloric acid quickly dissolves tin on heating, hydrogen being evolved and stannous chloride being formed. Dilute sulphuric acid has but little action on the metal; when heated with concentrated sulphuric acid, sulphur dioxide is evolved. Dilute nitric acid dissolves tin in the cold without evolution of gas; concentrated nitric acid acts vigorously upon the metal, whereby oxide of tin, which is insoluble in the acid, is formed. Alkaline lyes dissolve the metal to sodium stannate, hydrogen being thereby evolved.

*Tin baths.* The bath used by Roseleur for tinning with the battery works very well. It is composed as follows:

I. Pyrophosphate of soda 3.5 ozs., tin-salt (fused) 0.35 oz., water 10 quarts. To prepare the bath dissolve the pyrophosphate of soda in 10 quarts of rain water, suspend the tin-salt in a small linen bag in the solution, and move the bag to and fro until its contents are entirely dissolved.



*Objects of zinc, copper, and brass* are directly tinned in this bath with a current of slight tension. Articles of *iron* and *steel* are first coppered or preliminarily tinned in a bath prepared according to formula VIII., the deposit of tin being then augmented in bath I. with the battery current. Cast-tin anodes as large as possible are used, which, however, will not keep the content of tin in the bath constant. It is, therefore necessary, from time to time, to add tin-salt, which is best done by preparing a solution of 3.5 ozs. of pyrophosphate of soda in 1 quart of water and introducing into the solution tin-salt as long as the latter dissolves clear. Of this tin essence add to the bath more or less, as may be required, and also augment the content of pyrophosphate of soda, if, notwithstanding the addition of tin-salt, the deposition of tin proceeds sluggishly.

Though the bath composed according to formula I. suffices for most purposes, an alkaline tin bath, first proposed by Elsner, and later on recommended by Maistrasse, Fearn, Birgham, and others, with or without addition of potassium cyanide, may be mentioned as follows:—

II. Crystallized tin-salt 0.7 oz., water 1 quart, and potash lye of 10° Beaumé until the precipitate formed dissolves.

As seen from the formula the solution of tin-salt is compounded with potash lye of the stated concentration (or with a solution of 1 oz. of pure caustic potash in water), until the precipitate of stannous hydrate again dissolves.

Some operators recommend the addition of 0.35 oz. of potassium cyanide to the solution.

Without potassium cyanide the bath requires 3.75 to 4 volts, and with it, 3.5 volts.

In testing Salzède's bronze bath (p. 292), it was found to yield quite a good deposit of tin directly upon *cast-iron*, and it was successfully used for this purpose by omitting the cuprous chloride and using 14.11 drachms of stannous chloride, so that the composition became as follows:

IIa. 98 per cent. potassium cyanide 3.5 ozs., carbonate of potassium 35  $\frac{1}{4}$  ozs., stannous chloride 14.11 drachms, water 10 quarts. With 4 volts a heavy deposit was rapidly obtained.

III. A tin bath of stannous chloride, caustic soda and potassium cyanide, given by Pfanhauser, contains  $11\frac{1}{4}$  drachms of stannous chloride, equal to about  $7\frac{1}{2}$  drachms of metallic tin per quart. It is still more advantageous to use double the quantity of tin, the composition of the bath being then as follows:

Water 10 quarts, fused stannous chloride 14 ozs., caustic soda  $17\frac{1}{2}$  ozs., 100 per cent. potassium cyanide  $3\frac{1}{2}$  ozs.

The bath, as above composed contains about 15 drachms of metallic tin per quart, and with  $3\frac{1}{2}$  volts furnishes a deposit of tin of about  $4\frac{3}{4}$  grains per hour.

Pfanhauser has made new experiments and found that still more favorable results are obtained with a solution of  $1\frac{1}{2}$  ozs. of stannio-ammonium chloride in 1 quart of water, a deposit of  $9\frac{1}{2}$  grains of tin per hour being obtained with a current of only  $1\frac{1}{2}$  volts.

The solution of the salt is readily effected. Cast-tin anodes are to be used.

The temperature of the bath should be between  $68^{\circ}$  and  $77^{\circ}$  F. In case the bath becomes poor in metal, stannio-ammonium chloride is added.

The deposit of tin is rather rough, but can be readily made bright by treatment with brass scratch-brushes.

IV. A tin bath given by Taucher is composed as follows: Water 500 quarts, sodium or pyrophosphate 11 lbs., crystallized tin-salt 21 ozs., or, still better, fused tin salt  $17\frac{1}{2}$  ozs.

Bring the water into a tank completely lined with plates or anodes of tin joined together and connected with the positive pole wire. Dissolve the pyrophosphate in the water, stirring constantly. Place the tin-salt in a copper sieve, and immerse the latter about one-half in the solution; an abundant milky turbidity is immediately formed, which, however, disappears on stirring. When all the tin-salt is dissolved, remove the sieve, and the tin-bath, which now forms a clear fluid, either colorless or of a slightly yellowish color, is ready for use, it being only necessary to secure the articles to be tinned to the rods

connected with the negative pole. The anodes do not suffice to keep the bath saturated, and hence, when the deposit becomes weaker, small quantities of equal parts of tin-salt and of sodium pyrophosphate have to be added. The solution of these salts should always be effected with the assistance of a sieve to prevent small pieces of tin-salt from falling to the bottom of the bath, where they would be enveloped by an almost insoluble crust and remain nearly unchanged.

This tin bath is suitable for all kinds of metals, the deposit obtained combining, with considerable solidity, a matted and white appearance closely resembling silver.

*Management of tin baths.*—Tin baths should not be used at a temperature below 68° F. They require (formulae I. and II.), according to their composition, a current of 2 to 3 volts, so that two Bunsen elements coupled one after the other suffice for all purposes. Too strong a current causes a pulverulent reduction of the tin, which does not adhere well, while with a suitable current-strength quite a dense and reguline deposit is obtained. Cast-tin plates with as large a surface as possible are used as anodes. The choice of the tin-salt exerts some influence upon the color of the tinning. By using, for instance, crystallized tin-salt, which is always acid, in preparing the bath according to formula I., a beautiful white tinning with a bluish tinge is obtained, which, however, does not adhere so well as that produced with fused tin-salt. Again, the latter yields a somewhat dull gray layer of tin, and, therefore, the effects of the bath will have to be corrected by the addition of one or the other salt.

As previously mentioned, *iron* and *steel objects* are best subjected to a light preliminary tinning by boiling in the bath VIII. However, instead of this preliminary tinning, they may first be electro-coppered and, after scratch-brushing the copper deposit, brought into the tin bath.

When the action of the bath becomes sluggish, it has to be refreshed (for formula I.) by the addition of tin-salt and pyrophosphate of soda, or (for formula II.) by the addition of potash lye and tin-salt.

*Process of tin-plating.*—From what has been said, it will be evident that the execution of tin-plating is simple enough. After being freed from grease and pickled, the objects are brought into the bath and plated with a weak current. For heavy deposits the objects are frequently taken from the bath and thoroughly brushed with a brass scratch-brush, not too hard, and moistened with dilute sulphuric acid (1 part acid of 66° Bé. to 25 water) and, after rinsing in water, are returned to the bath. If, with the use of too strong a current, the color of the deposit is observed to turn a dark dull gray, scratch-brushing must be repeated. When the tinning is finished the articles are brushed with a brass scratch-brush and decoction of soap-root, then dried in sawdust, and polished with fine whiting.

*Tinning by contact and boiling.*—For tinning by zinc-contact in the boiling tin bath the following solutions may be recommended:

V. According to Gerhold: Pulverized tartar and alum, of each 3.5 ozs., fused stannous chloride 14 drachms, rain-water 10 quarts.

VI. According to Roseleur: Potassium pyrophosphate 7 ozs., crystallized stannous chloride (tin-salt), 11 drachms, fused stannous chloride 2.8 ozs., rain-water 10 quarts.

VII. According to Roseleur, for tinning by *immersion*: Potassium pyrophosphate 5.6 ozs., fused stannous chloride 1.23 ozs., rain-water 10 quarts.

Formulæ V. and VI. yield good results. For tinning by contact, heat the bath to boiling and suspend the clean and pickled objects in contact with pieces of zinc, or, better, wrapped around with zinc wire spirals, care being had from time to time to shift them about to prevent staining. Large baths which cannot be readily heated are worked cold, the objects being covered with a large zinc plate. In the cold bath the formation of the tin deposit requires, of course, a longer time. By using the electric current the deposit can be made as heavy as desired. By immersion in the bath prepared according to formula VII., zinc



can only be coated with a very thin film of tin, which, however, by the use of a battery, can be made as heavy as desired.

For tinning by contact in a cold bath, Zilken has patented the following solution: Dissolve with the aid of heat in 100 quarts of water, tin-salt 7 to 10.5 ozs., pulverized alum 10.5 ozs., common salt  $15\frac{3}{4}$  ozs., and pulverized tartar 7 ozs. The cold solution forms the tin bath. The objects to be tinned are to be wrapped round with strips of zinc. Duration of the process 8 to 10 hours.

VIII. *Tinning solution for iron and steel articles.*—Crystallized ammonium-alum 7 ozs., crystallized stannous chloride 2.8 drachms, fused stannous chloride 2.8 drachms, rain-water 10 quarts. Dissolve the ammonium-alum in the hot water, and when dissolved add the tin-salts. The bath is to be used boiling hot and kept at its original strength by an occasional addition of tin-salt. The clean and pickled iron objects, after being immersed in the bath, become in a few seconds coated with a firmly adhering film of tin of a dead, white color, which may be polished by scratch-brushing or scouring with sawdust in the tumbling-barrel. Tinning by boiling in this bath is the most suitable preparation for iron and steel objects, which are to be provided with a heavy electro-deposit of tin. To be entirely sure of success it is recommended thoroughly to scratch-brush the objects, then to return them once more to the bath, and finally to suspend them in a bath composed according to formula I. or II.

*A tinning solution for small brass and copper articles* (pins, eyes, hooks, etc.), consists of a boiling solution of: Pulverized tartar 3.5 ozs., stannous chloride (tin-salt) 14.11 drachms, water 10 quarts. After heating the bath to the boiling-point, immerse the objects to be tinned in a tin sieve or in contact with pieces of zinc in a stoneware sieve. Frequent stirring with a tin rod shortens the process.

*Another solution*, given by Böttger, also yields good results: Dissolve oxide of tin by boiling with potash lye, and place the copper or brass objects to be tinned in the boiling solution in contact with tin shavings.

*Elsner's bath* yields equally good results. It consists of a solution of equal parts of tin-salt and common salt in rain-water. The manipulation is the same as given above.

A durable coating of tin is also produced with the use of potassium stannate, which is prepared as follows: Tin is melted and then granulated by pouring it into water. The granulated tin is brought into a vessel of glass or porcelain, and crude nitric acid poured over it, whereby, with strong effervescence of the fluid and the evolution of brown-red vapors, it is converted into a white powder consisting of stannic oxide. The latter is separated from the unchanged tin by washing with water and dried. The dry powder is mixed with pure potash in the proportion of 3 parts stannic oxide and 4 parts potash. The mixture is melted in an iron crucible and the fused mass poured upon a stone slab. It consists of potassium stannate and is dissolved in boiling water. Potassium stannate may also be prepared by adding to a solution of tin-salt in water, aqua ammonia so long as a precipitate is formed. The mass is then allowed to drain off upon a linen cloth and repeatedly washed with water. The residue, consisting of stannous hydrate, is boiled with strong potash lye, and the solution of potassium stannate thus obtained diluted with water.

Needles are tinned by spreading them out upon a sieve and immersing the latter in the bath; larger articles are touched with a tin rod while in the bath. The temperature of the bath should be between  $122^{\circ}$  and  $212^{\circ}$  F. Larger articles of brass or bronze are best coppered previous to tinning by wrapping them with iron wire and immersing them in dilute sulphuric acid for a short time; hydrochloric acid may be substituted for the sulphuric acid.

Tinning may also be effected by dissolving 1 part tin-salt in 10 parts water, adding to the solution one of 2 parts of caustic potash in 20 of water, and stirring until the fluid is clear. The articles to be tinned are placed upon a tin plate. The latter is brought into the hot bath and touched on several places with tin rods.

To give articles of brass, copper or iron a thin, superficial coating of tin, dip them in a solution of tin-salt in which granulated tin has been lying for some time, then dust them with tin-powder, rub them with a woollen rag, and repeat the operation until the article appears tinned.

*A characteristic method of tinning* by Stolba is as follows: Prepare a solution of 1.75 ozs. of tin-salt and 5.64 drachms of pulverized tartar in one quart of water; moisten with this solution a small sponge and dip the latter into pulverulent zinc. By then rubbing the thoroughly cleansed and pickled articles with the sponge, they immediately become coated with a film of tin. To obtain uniform tinning, the sponge must be repeatedly dipped now into the solution and then into the zinc-powder, and the rubbing continued for a few minutes.

For *coloring and patinizing tin*, see special chapter.

## 2. DEPOSITION OF ZINC.

*Properties of Zinc.*—Zinc is a bluish-white metal, possessing high metallic lustre. It melts at  $776^{\circ}$  F. At the ordinary temperature zinc is brittle, but it is malleable at between  $212^{\circ}$  and  $300^{\circ}$  F., and can be rolled into sheets. At  $392^{\circ}$  F. it again becomes brittle and may be readily reduced to powder. The specific gravity of zinc varies from about 6.86 to 7.2. When strongly heated in the air or in oxygen it burns with a greenish-white flame, producing dense white fumes of the oxide.

In moist air it becomes coated with a thin layer of basic carbonate, which protects the metal beneath from further oxidation. Pure zinc dissolves slowly in the ordinary mineral acids, but the commercial article containing foreign metals is rapidly attacked, hydrogen being evolved.

Since zinc is a very electro-positive metal, it precipitates most of the heavy metals from their solutions, especially copper, silver, lead, antimony, arsenic, tin, cadmium, etc., this being the reason why in dissolving impure zinc the admixed metals do not pass into solution so long as zinc in excess is present.

Caustic alkalies also dissolve zinc, an oxide and free hydrogen being formed, especially when it is in contact with a more electro-negative metal.

Zinc in contact with iron protects the latter from rust, and also prevents copper from dissolving when in contact with it.

*Zinc baths.*—Although most metals can be readily plated with a thin, firmly-adhering layer of zinc, the production of uniform deposits of pure zinc upon large shaped articles is attended with difficulties, because zinc baths do not work quite well in the deeper portions. Better results are obtained in plating articles with depressions by depositing not pure zinc, but zinc in combination with other metals. Of course, zinc must be largely in excess if the deposit is to have the same effect as pure zinc in protecting the plated article from rust. By the addition of salts of magnesium and aluminium to the zinc bath, Schaag, Dr. Alexander and others have endeavored to deposit zinc in combination with these metals. While the possibility of depositing aluminium from aqueous solutions is doubtful, it is very likely that in Schaag's as well as in Dr. Alexander's patented process neither the magnesium nor the aluminium is the effective agent, but the tin or mercury salts which are also added to the bath. But such additions are nothing new, since deposits of zinc-tin alloys with or without mercury salts have for many years been produced. The same object is attained by an addition of tin and nickel to the zinc bath, and experiments have conclusively shown that deposits upon iron produced in such a bath protect the iron from rust as well as a deposit produced in a bath of pure zinc, or in Dr. Alexander's patented zinc baths.

Below the pure zinc baths mostly used are given :

I. Sulphate of zinc (white vitriol) 2.8 ozs., ammonium sulphate  $1\frac{3}{4}$  ozs., sal ammoniac 11 drachms, water 1 quart. Dissolve the salts in the heated water and use the bath at  $68^{\circ}$  F. The current-strength should only be slightly greater than necessary for the decomposition of the bath. The current of two Bunsen elements coupled one after the other is quite too



strong, and must, therefore, be suitably weakened by the resistance-board.

As anodes, rolled zinc sheets of not too small dimensions are to be used. This bath is suitable for a thick deposit upon objects (sheets and plates) of *wrought- and cast-iron, steel*, and all other metals, but not for plating hollow articles if anodes cannot at equal distances be placed around them. The most suitable tension is 2.8 to 3 volts.

II. Caustic potash 2 ozs., chloride of zinc  $5\frac{1}{2}$  drachms, sal ammoniac 11 drachms, water 1 quart. Dissolve the caustic potash in one-half of the water, and the chloride of zinc and sal ammoniac in the other half, and mix both solutions, stirring constantly. The result is a clear fluid, which requires a current of 2.5 to 3 volts for its decomposition. In consequence of the action of the caustic potash upon the sal ammoniac, this bath evolves ammonia, the odor of which is very annoying. Experiments have proved that plating of cast-iron in this bath is not successful. Zinc sheets are used as anodes. In this bath the deposit upon shaped articles proceeds better than in the preceding, though frequent turning of the objects is required.

III. Alum  $3\frac{1}{2}$  ozs., hydrated oxide of zinc  $5\frac{1}{2}$  drachms, water 1 quart. Dissolve 14 drachms of sulphate of zinc in 1 pint of water, and carefully add potash lye until a further drop of it no longer produces a precipitate. Since potash lye dissolves the hydrated oxide of zinc, an excess has to be avoided. The precipitate is filtered off, washed with water, and the hydrated oxide of zinc, while still moist, is heated together with the solution of  $3\frac{1}{2}$  ozs. of alum in 1 quart of water, whereby it is completely dissolved. This bath requires a current of 3 to 3.5 volts.

IV. Sulphate of zinc (white vitriol) 2.8 ozs., water 1 quart, and potash lye sufficient so redissolve the precipitated hydrated oxide of tin. This bath also works quite well, and requires from 2.75 to 3 volts and 1.5 ampères per  $15\frac{1}{2}$  square inches.

Solution of cyanide of zinc in potassium cyanide may also

be used for zinc-plating, such a bath having been warmly recommended by some authors. However, the production of deposits of some thickness requires a long time, and the deposit itself shows a tendency to peel off.

*Execution of zinc-plating.*—Next to thorough cleansing and pickling the objects, especially iron castings, and regulating the current, zinc-plating depends on the frequent turning and changing the objects in the bath, since the deposit is chiefly formed upon the portions nearest to the anodes, and not at all, or with difficulty, upon the portions away from the anodes. If, notwithstanding frequent changing, some portions do not acquire a deposit, recourse must be had, as in nickeling, to the hand anode. Next to frequently changing the articles in the bath, it is recommended to scratch-brush them several times, especially if heavy deposits are to be produced. It is also advisable to somewhat heat the baths, if possible.

It is of advantage to superficially zinc iron objects by a combined process of contact and boiling, and then to augment the layer of zinc in the bath.

After thorough scratch brushing with a steel brush, not too hard, and a decoction of soap-root, the zincked objects are rinsed in lime-water, then plunged into hot water, and dried in saw-dust. Polishing is effected upon soft cloth bobs with Vienna lime and oil.

*Zinc-plating of wrought-iron objects, girders, L-iron, T-iron, etc.*—For this purpose, Pfanhauser gives the following directions. By way of introduction it may be observed that under this heading will be considered the plating with zinc of wrought-iron objects of considerable length and width. It is generally sought to protect such objects from rust by a coat of oil paint, but it is well known that such protection does not last very long, and the coat of paint has to be renewed every year, or at least every second or third year.

However, for such objects as are used in the construction of bridges, etc., a good deposit of zinc is a guarantee for long durability, and in constructions where the coat of paint cannot

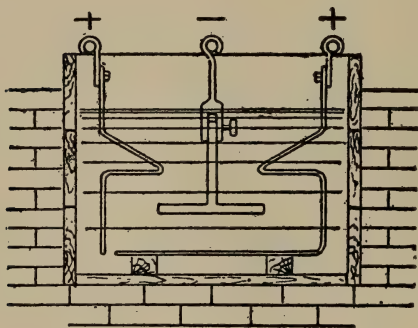
be renewed or repaired, such deposit is of immense value. For solidly plating with zinc such larger objects, Pfanhauser recommends the following bath:

Water 1 quart, zinc sulphate  $6\frac{1}{2}$  ozs., ammonium sulphate  $1\frac{3}{4}$  ozs. Temperature of the bath,  $59^{\circ}$  to  $68^{\circ}$  F.; concentration,  $14\frac{1}{2}^{\circ}$  Bé.

The bath is prepared as follows:

After having decided how many gallons of bath are to be prepared, dissolve in one quarter of the quantity of water required (best warm) the zinc sulphate, and in one-half of the total quantity of water, the ammonium sulphate. The solution of

FIG. 139.



the ammonium sulphate may be effected in the plating vat itself, but the zinc sulphate has to be dissolved in a special vessel indifferent to changes in temperature. When all the ammonium sulphate is dissolved, pour in the zinc sulphate solution, whilst constantly stirring, and finally add the last quarter of the required quantity of water. The bath works well at once, without boiling or previous working through with the current.

The objects are best cleansed by means of the sand blast.

A profile anode corresponding to the shape of the article to be plated is to be used, and it is so arranged in the bath that all parts of the object are approximately at the same distance

from it. Fig. 139, for instance, shows the arrangement of the anode in zincking a simple girder.

*Zincking of nails, screws, etc.*—Such articles are zincked in a capacious wire basket which is horizontally suspended, or in a revolving drum. Cleaning in alkaline solutions and pickling is troublesome and not practicable, because after being for a short time exposed to the air the objects commence to rust. Hence, it is best to scour them (best dry) in a tumbling barrel partially filled with quartz sand or emery powder. When working on a large scale the sand blast shown in Fig. 87, p. 140, may be used to advantage.

A suitable bath for zincking nails, screws, etc., is composed as follows: Water 10 quarts, zinc sulphate 35 ozs., ammonium chloride  $8\frac{1}{2}$  ozs., ammonium citrate 14 ozs. Temperature of the bath,  $59^{\circ}$  to  $68^{\circ}$  F.; concentration of the bath,  $10\frac{1}{2}^{\circ}$  Bè.

Zinc plates 0.19 to 0.39 inch thick are to be used as anodes.

As previously mentioned, better results are obtained with all zinc baths by heating them to from  $104^{\circ}$  to  $122^{\circ}$  F. In baths thus heated, very voluminous objects, short pipes, larger iron castings, etc., have been successfully plated with the use of level anodes, which in cold baths could have been effected only with great difficulty and by employing special precautionary measures.

For *zincking iron by contact* quite a concentrated solution of chloride of zinc and sal ammoniac in water is required. The objects are placed in the solution in contact with large surfaces of zinc.

*To coat brass and copper* with a bright layer of zinc proceed as follows: Boil for several hours commercial zinc-gray, *i. e.*, very finely-divided metallic zinc, with concentrated solution of caustic soda. Then immerse the articles to be zincked in the boiling fluid; when, by continued boiling, they will in a short time become coated with a very bright layer of zinc. When a copper article thus coated with zinc is carefully heated in an oil bath to between  $248^{\circ}$  and  $284^{\circ}$  F., the zinc alloys with the copper, forming a sort of bronze similar to tombac.



Weil zincks copper and coppered objects by immersing them in a boiling concentrated solution of caustic potash in contact with zinc. The coating thus obtained is said to be adherent and brilliant.

For *coloring* and *patinizing zinc*, see special chapter.

*Zinc alloys.*—The production of the principal zinc alloy, brass, by the galvanic method, having already been mentioned, and also that of a zinc-nickel-copper alloy (German silver), it remains to give an alloy of zinc with tin, or of zinc, tin and nickel, which can be produced by the use of the battery.

A suitable bath for depositing this alloy consists of: Chloride of zinc  $6\frac{3}{4}$  drachms, crystallized stannous chloride 9 drachms, pulverized tartar 9 drachms, pyrophosphate of soda  $2\frac{3}{4}$  drachms, water 1 quart. Dissolve the salt at a boiling heat, and filter the cold solution, when it is ready for use. For anodes, cast plates of equal parts of tin and zinc are used.

These deposits have no special advantages, but, on the other hand, a deposit containing zinc in large excess has the same effect of protecting iron from rust as a deposit of pure zinc.

By preparing a bath which contains as conducting salt sodium citrate, and ammonium chloride and the chlorides of the metals in the proportion of 4 zinc chloride to 1 tin chloride, a deposit is obtained, which not only is a perfect protection against rust, but also enters far better into depressions than pure zinc. By adding to the bath a small quantity of chloride of mercury, or of nickel, alloys of zinc, tin and mercury, or of zinc, tin and nickel are formed, which are distinguished from pure zinc deposits by a finer structure.

### 3. DEPOSITION OF LEAD.

The properties of lead only interest us in so far as it is less attacked by most mineral acids than any other metals, and objects have been coated with it, in order to protect them against the action of such agents. For decorative purposes electro-deposits of lead are not used, and those as a protection against chemical influences cannot be produced of sufficient thickness for that purpose.

*Lead baths.*—I. Dissolve, by continued boiling, caustic potash 1.75 ozs. and finely pulverized litharge 0.17 oz. in 1 quart of water.

II. According to Watt, the following solution is used: Acetate of lead 0.17 oz., acetic acid 0.17 oz., water 1 quart.

The bath prepared according to formula I. deserves the preference.

Lead baths require anodes of sheet-lead or cast-lead plates, a very weak current, and in order to produce a dense deposit of some thickness, the objects have to be frequently scratch-brushed. Iron is best previously coppered. Superoxide of lead being separated from the anodes, they have to be frequently cleansed with a scratch-brush. The formation of superoxide of lead is utilized for the production of the so-called Nobili's rings (electrochromy), which will be mentioned below.

To coat *gun barrels and other articles of steel or iron* with superoxide of lead as a protection against rust, suspend the bright articles as anodes in a solution of nitrate of lead mixed with ammonium nitrate.

*Leading by contact* is effected by suspending the objects, previously thoroughly freed from grease, in the boiling solution prepared according to formula I., in contact with a piece of tin.

*Metallo-chromes (Nobili's rings, iridescent colors, electrochromy).* The separation of superoxide of lead upon the anodes or upon objects suspended as anodes, produces superb effects of colors. For the production of such colors, a bath is prepared by boiling for half an hour  $3\frac{1}{2}$  ozs. of caustic potash, 14 drachms of litharge, and 1 quart of water. The operation is as follows: Suspend the articles, carefully freed from grease and pickled, to the anode-rods, and with a weak current introduce in the lead solution a thin platinum wire connected with the object-rod by flexible copper wire, without, however, touching the article. The latter will successively become colored with various shades—yellow, green, red, violet, and blue. By the continued action of the current, these colors pass into a

discolored brown, which also appears in the beginning if the current be too strong, or the platinum wire be immersed too deep. Such unsuccessful coloration has to be removed by rapidly dipping in nitric acid, and, after rinsing in water, suspending the article in the bath. For coloring not too large surfaces, a medium-sized Bunsen element is, as a rule, sufficient, if the platinum wire be immersed about  $\frac{3}{4}$  inch.

Colors of all possible beautiful contrasts may be obtained by perpendicularly placing between the objects to be colored and the platinum wire a piece of stout parchment paper, or providing the latter with many holes or radial segments.

Another process of producing these effects of colors is as follows: Prepare a concentrated solution of acetate of lead (sugar of lead), and after being filtered, pour it into a shallow porcelain dish. Then immerse a plate of polished steel in the solution, and allow it to rest upon the bottom of the dish. Now connect a small disc of sheet copper with the wire proceeding from the zinc element of a constant battery of two or three cells, the wire connected with the copper element being placed in contact with the steel plate. If now the copper disc be brought as close to the steel plate as possible without touching it, in a few moments a series of beautiful prismatic colorations will appear upon the steel surface, when the plate should be removed and rinsed in clean water. These colorations are films of lead in the form of peroxide, and the varied hues are due to the difference in thickness of the precipitated peroxide of lead, the light being reflected through them from the polished metallic surface beneath. By reflected light every prismatic color is visible, and by transmitted light a series of prismatic colors complementary to the first colors will appear occupying the place of the former series. The colors are seen to the greatest perfection by placing the plate before a window with the back to the light, and holding a piece of white paper at such an angle as to be reflected upon its surface. The colorations are not of a fugitive character, but will bear a considerable amount of friction without being removed. In proof

of the lead oxide being deposited in films or layers, it may be stated that if the deposit be allowed to proceed a few seconds beyond the time when its greatest beauties are exhibited, the coloration will be less marked, and become more or less red, green or brown. If well rubbed, when dry, with the finger or fleshy part of the hand, a rich blue colored film will be laid bare by the removal of the delicate film above it.

The plan recommended by Mr. Gassiot to obtain the metallo-chromes is to place over the steel plate a piece of card cut into some regular device, and over this a rim of wood, the copper disc being placed above this. Very beautiful effects are obtained when a piece of fine copper wire is turned up in the form of a ring, star, cross or other pattern, and connected with the positive electrode, this being in fact one of the simplest and readiest methods of obtaining the colorations upon the polished metal. Metallo-chromy is extensively employed in Nuremberg to ornament metallic toys. It has been adopted in France for coloring bells, and in Switzerland for coloring the hands and dials of watches. In using the lead solutions to produce metallo-chromes, it must be remembered that metallic lead becomes deposited upon the cathode, consequently the solutions in time become exhausted, and must therefore be renewed by the addition of the lead salt.

#### 4. DEPOSITION OF IRON (STEELING).

The principal practical use of the electro-deposition of iron is to coat printing plates of softer metal to increase their wearing qualities. We are indebted to Böttger for calling attention to the employment of iron deposits, but notwithstanding the efforts of many scientific and practical men to improve the process, the expectation entirely to replace copper galvanoplasty for clichés by iron-galvanoplasty has not been fulfilled.

Only such baths as are suitable for steeling will here be given. Solutions for the production of thick iron deposits, and the conditions under which they can be obtained, will be referred to later on under "Galvanoplasty in Steel."



*Iron (steel) baths.* — I. According to Varrentrapp: Pure green vitriol  $4\frac{3}{4}$  ozs., sal ammoniac  $3\frac{1}{2}$  ozs., water 1 quart. Boil the water for  $\frac{1}{2}$  hour to expel all air, and, after cooling, add the green vitriol and sal ammoniac. By the action of the air, and the oxygen appearing on the anodes, this bath is readily decomposed, insoluble basic sulphate of iron being separated as a delicate powder, which has to be frequently removed from the fluid by filtering. To decrease decomposition, the double sulphate of iron and ammonium, which can be more readily obtained pure and free from oxide, may be used.

II. Sal ammoniac  $3\frac{1}{2}$  ozs., water 1 quart. This neutral solution of sal ammoniac may be made into an iron bath by hanging in it iron sheets as anodes, suspending an iron or copper plate as cathode, and allowing the current to circulate until a regular separation of iron is attained, which is generally the case in 5 to 6 hours. Although a separation of hydrated oxide of iron also takes place in this bath, it does so in a less degree than in that prepared according to Formula I. For the production of not too heavy a deposit of iron, some operators claim to have obtained the best results with this bath.

According to Böttger, the following bath serves for steeling:

III. Potassium ferrocyanide (yellow prussiate of potash) 0.35 oz., Rochelle salt 0.7 oz., distilled water 200 cubic centimeters. To this solution is added a solution of 1.69 drachms of persulphate of iron in 50 cubic centimeters of water, whereby a moderate separation of Berlin blue takes place. Then add, drop by drop, whilst stirring constantly, solution of caustic soda until the blue precipitate has disappeared. The clear, slightly yellowish solution thus obtained can be used directly for steeling.

A heavy and very hard deposit of iron is obtained in a bath of the following composition:

IV. Ammonio-ferrous sulphate  $1\frac{1}{4}$  ozs., crystallized citric acid 0.88 oz., water 1 quart; sufficient ammonia for alkaline reaction.

For steeling his copper printing plates, which are frequently

of quite large dimensions, C. Obernetter, of Munich, employs the following method: The plate to be steeled is first freed from all color, which is best effected by means of chloroform or oil of turpentine. It is then thoroughly washed and brushed by means of a bristle-brush with potash lye, or a solution of 1 part potassium cyanide in 20 parts water, and again washed. In this state the plate is suspended to the cathode of the steeling bath. A clean steel plate serves as anode. Both the anode and cathode are in a horizontal position. Bubbles forming on the cathode are readily removed by means of a feather. In about five minutes the plate is thoroughly steeled.

The iron bath consists, according to Obernetter, of ferrous sulphate 30 parts by weight, iron-alum 30, sal ammoniac 60, dissolved in warm distilled water 1000.

The solution is allowed to stand for two days, and is then filtered twice. It should also be filtered every time before use.

After steeling, the plate is cleansed in the above-described manner, and oiled to prevent rusting.

When, during the operation of printing, the deep places of the plate commence to become red, *i. e.*, when the copper shines through, the steeled plate may be re-steeled, but, according to Obernetter, this should not be done more than once. It is best in every case to first remove the old steeling with dilute sulphuric or nitric acid, and then to re-steel the plate.

According to Obernetter's statements, 21,000 copies were printed from a plate thus steeled without the plate suffering any injury, the last impression being in every respect equal to the first.

For decorative purposes, a deep black deposit of iron may, according to "La Metallurgie," be produced as follows: Dissolve as large a quantity of steel filings as possible in 50 quarts of commercial hydrochloric acid. The saturation of the solution is recognized by a sediment, which no longer dissolves, being formed on the bottom of the vessel. Then add 2 lbs. of white arsenic, and vigorously stir the mixture. The arsenic

dissolves very slowly, but the bath cannot be considered finished until all of it is dissolved, and the color obtained by means of the bath is the deeper the more complete the solution of the arsenic. The articles to be treated are connected to the negative pole of the battery, iron and carbon plates serving as anodes. For a bath of 50 quarts, two Bunsen elements about  $7\frac{3}{4}$  inches high are required, and the bath being very acid, the articles must be connected with the battery prior to immersion. Upon copper and brass the deposit is directly produced, but iron articles, being attacked by the bath, are first provided with a coat of nickel. The deposit of iron upon this nickel coating is very beautiful, and has been designated as "black nickeling." The coating must, of course, be protected from oxidation by a colorless lacquer.

*Management of iron baths.*—As previously mentioned, the insoluble precipitate from time to time formed in the bath has to be removed by filtration. This precipitate is, however, very delicate, and when stirred up might settle upon the objects and prevent the adherence of the deposit. It is, therefore, advisable to use for steel baths, tanks of much greater depth than corresponds to the height of the objects, whereby the stirring up of the sediment in suspending the objects is best avoided. The baths must be kept thoroughly neutral, which may be effected in various ways. One method is to suspend small linen bags filled with carbonate of magnesia in the bath. Another method, which has been used with decided success, consists in precipitating, whilst excluding the air as much as possible, a solution of pure green vitriol with ammonium carbonate, quickly filtering off the ferrous carbonate, washing the latter once or twice in cold water previously boiled, stirring it while moist into the bath, and allowing to repose for one hour.

The cleansed and pickled objects are plated in the baths according to formulæ I. and II., with a current of 1.5 to 2 volts, and the anodes at a distance of 4 to  $4\frac{3}{4}$  inches, after which the current is reduced to 1 or 1.25 volts. To produce iron deposits of any kind of thickness, the escape of the hy-

drogen bubbles which settle on the objects must be promoted by frequent blows with the finger upon the object-rod. As anodes, iron sheets of a large surface freed from scale by pickling are to be used. When steeling is finished, the articles are thoroughly rinsed, then plunged into very hot water, and, after drying in sawdust, placed for several hours in a drying chamber heated to about  $212^{\circ}$  F., to expel all moisture from the pores.

Steeling of printing plates has the advantage over nickeling, that when the plates are worn they can be rapidly freed from the deposit by dilute sulphuric acid or very dilute nitric acid, and re-steeled. It has been ascertained by experiments that the capability of resistance of steeled plates is less than that of nickeled plates, 200,000 impressions having been made with the latter without any perceptible wear.

For steeling printing plates a bath prepared according to formula I. or II. is very suitable.

*Steeling by contact* is readily effected by touching the metallic objects with zinc, best in a bath prepared according to formula I.



## CHAPTER XIII.

### DEPOSITION OF ANTIMONY, ARSENIC, ALUMINIUM.

#### I. DEPOSITION OF ANTIMONY.

*Properties of antimony.*—Electro-deposited antimony possesses a gray lustre, while native, fused antimony shows a silver-white color. Antimony is hard, very brittle, and may easily be reduced to powder in a mortar. It melts at  $842^{\circ}$  F., and at a strong red heat takes fire and burns with a white flame, forming the trioxide. Its specific gravity is 6.8. It is permanent in the air at ordinary temperatures. Cold, dilute or concentrated sulphuric acid has no effect upon antimony, but the hot concentrated acid forms sulphide of antimony. By nitric acid the metal is more or less energetically oxidized, according to the strength and temperature of the acid.

*Antimony baths.*—Electro-depositions of antimony are but seldom made use of in the industries, though they are very suitable for the production of contrasts in decorating. Gore discovered the explosive power of deposits of antimony chloride or of antimony containing hydrochloric acid. According to Gore, a bath consisting of tartar emetic 3 ozs., hydrochloric acid  $4\frac{1}{4}$  ozs., tartaric acid 3 ozs. and water 1 quart, yields a gray crystalline deposit of antimony. This bath requires a current of about three volts. The deposit possesses the property of exploding when scratched with a hard object. This explosion is caused by a content of chloride of antimony. Böttger found 3 to 5 per cent. of chloride of antimony in the deposit, and Gore 6 per cent. A similar explosive deposit is obtained by electrolyzing a simple solution of chloride of antimony in hydrochloric acid (liquid butter of antimony, *liquor stibii chlorati*) with the current.

A lustrous non-explosive deposit of antimony is obtained by boiling 4.4 ozs. of carbonate of potash, 2.11 ozs. of pulverized antimony sulphide, and 1 quart of water for 1 hour, replacing the water lost by evaporation, and filtering. Use the bath boiling hot, employing cast antimony plates or platinum sheets as anodes.

An antimony bath which yields good results is composed as follows:

Schlippe's salt  $1\frac{3}{4}$  ozs., water 1 liter. Dissolve the salt in the water. Tension required, 4 volts. An unpleasant feature of this bath is that during electrolyzing sulphuretted hydrogen escapes, which limits its application.

Schlippe's salt, named after its discoverer, is easily formed by boiling an aqueous solution of sodium sulphide with antimony trisulphide and sufficient sulphur to convert it into the pentasulphide. Instead of sodium sulphide, caustic soda and sulphur may be used, which on boiling yield sodium sulphide and sodium thiosulphate; or, instead of caustic soda, sodium carbonate and slaked lime. To prepare the compound, 9 parts of crystallized sodium carbonate are boiled with 3 parts of slaked lime, 3 parts of antimony trisulphide, 1 part of sulphur, and sufficient water. The hot liquid is rapidly filtered off from the calcium carbonate and evaporated down until the salt crystallizes out. The crystals so obtained must be preserved in well-stoppered bottles, as the carbonic anhydride of the air decomposes them, forming sodium carbonate, sulphuretted hydrogen and antimony sulphide. This causes the colorless, or, at most, pale yellow crystals to become gradually covered with an amorphous brown-colored crust.

## 2. DEPOSITION OF ARSENIC.

*Properties of arsenic.* — Arsenic has a gray-white color, a strong metallic lustre, is very brittle, and evaporates at a red heat. In dry air arsenic retains its lustre, but soon turns dark in moist air. It is scarcely attacked by dilute hydrochloric and sulphuric acids, while concentrated sulphuric acid as well

as nitric acid oxidizes it to arsenious acid. If caustic alkalies are fused together with arsenic, a portion of the latter is converted into alkaline arsenate.

*Arsenic baths.*—Deposits of arsenic are more frequently used than antimony deposits for decorative purposes, in order to produce a blue-gray tone of a certain warmth, which is very effective in combination with bright copper, brass, etc.

A solution suitable for depositing arsenic upon all kinds of metals is as follows:

I. Pulverized arsenious acid  $1\frac{3}{4}$  ozs., crystallized pyrophosphate of soda 0.7 oz., 98 per cent. potassium cyanide  $1\frac{3}{4}$  ozs., water 1 quart.

Dissolve the pyrophosphate of soda and the potassium cyanide in the cold water, and after adding, whilst stirring, the arsenious acid, heat until the latter is dissolved. In heating, fumes containing prussic acid escape, the inhalation of which must be carefully avoided. The bath is used warm, and requires a vigorous current of at least 4 volts, so that, at the least, 3 Bunsen elements have to be coupled for tension. After suspending the objects they are first colored black-blue, the color passing with the increasing thickness of the deposit into pale blue, and finally into the true arsenic gray. Platinum sheets or carbon plates are to be used as anodes.

Instead of a bath prepared according to formula I., a solution of the following composition may be used:

II. Sodium arsenate  $1\frac{3}{4}$  ozs., 98 per cent. potassium cyanide 0.8 oz., water 1 quart. Boil the solution for half an hour, then filter and use it at a temperature of at least  $167^{\circ}$  to  $176^{\circ}$  F., with a strong current. It yields a good deposit.

Large baths, to be used cold, must be more concentrated, and require a stronger current than hot baths.

When the baths begin to work irregularly and sluggishly, they have to be replaced by fresh solutions.

In the execution of deposits of arsenic and antimony the same rules are to be observed as for the other electro-plating processes.

However, attention may here be called to one phenomenon which is frequently the cause of defective deposits. When, for instance, mountings of zinc, such as are used for book covers, jewel boxes, etc., are to be provided with a deposit of copper and arsenic, and hence are to show two colors, it is necessary to first copper them. After polishing and cleaning the coppered mountings, the places which are not to receive the blue-gray deposit of arsenic are coated with stopping-off varnish. When articles thus treated, after being again freed from grease and pickled, are brought into the arsenic bath, they frequently show ugly stains the size of a pin-head. This phenomenon, however, does not appear when the articles before being brought into the bath are drawn through water acidulated with a small quantity of nitric acid (about  $\frac{1}{3}$  oz. of nitric acid to 1 quart of water), and thoroughly rinsed in clean water.

*Deposits of antimony and arsenic by contact and immersion* are much used for coloring brass and copper, as well as iron (browning of gun-barrels), and silver. Most frequently a warm solution of antimony trichloride (the butter of antimony of commerce) in hydrochloric acid is used for this purpose, in which the clean and pickled brass articles acquire a coating of a steel-gray color with a bluish tinge. By using instead, a hot mixture of chloride of arsenic with a small quantity of water, a steel-gray color without a bluish tinge is obtained.

By immersing brass in a solution of 20 parts by weight of arsenious acid, 40 of hydrochloric acid, 800 of water, and 10 of sulphuric acid heated to between  $122^{\circ}$  and  $140^{\circ}$  F., it becomes black by the separation of pulverulent arsenic; after rinsing in water and drying the coat adheres quite well. By contact with zinc the deposit is obtained in a shorter time and adheres better.

### 3. DEPOSITION OF ALUMINIUM.

*Properties of aluminium.*—Aluminium is a white silvery metal with an almost imperceptible bluish tinge. It is extremely light, the specific gravity being only 2.58, is very malleable and



ductile, takes a high polish, and is not liable to tarnish in the air. It melts at about  $1300^{\circ}$  F. Its principal common impurities are iron and silicon.

Aluminium does not seem to possess any qualities which would make it advantageous as an electro-deposit upon other metals. Many solutions have been proposed which it was claimed should give good deposits of the metal, but, on trial, have been found to be worthless. The solutions given below are claimed to give good results, but are here mentioned with due reserve.

*Aluminium baths.*—I. Bertrand states that he has deposited aluminium upon a plate of copper in a solution of the double chloride of aluminium and ammonium by using a strong current from three Bunsen elements, the bath being worked at  $140^{\circ}$  F.

II. *Goze's process.*—Mr. Goze obtained a deposit of aluminium by the single-cell method from a dilute solution of the chloride. The liquid was placed in a jar in which was immersed a porous cell containing dilute sulphuric acid; an amalgamated zinc plate was immersed in the acid solution, and a plate of copper in the chloride solution, the two metals being connected by a copper conducting wire. At the end of some hours the copper plate became coated with a lead-colored deposit of aluminium, which when burnished, presented the same degree of whiteness as platinum, and did not appear to tarnish readily when immersed in cold water, or exposed to the atmosphere, but was acted upon by dilute sulphuric and nitric acids.

III. The following formula is given by Mr. Herman Reinbold, who states that it yields excellent results: Dissolve 50 parts by weight of alum in 300 of water, and to this add 10 parts of aluminium chloride. The solution is to be heated to  $200^{\circ}$  F., and, when cold, 39 parts of potassium cyanide are to be added. A feeble current should be used.

IV. A new method for the electro-deposition of aluminium is as follows: \* To a 20 per cent. solution of ammonium-alum

\* *Neueste Erfindungen und Erfahrungen*, vol. xix., p. 353.

in warm water, add a solution of about the same quantity of pearl-ash and of a small quantity of ammonium carbonate. The mixture effervesces and yields a precipitate, which is filtered off and thoroughly washed with water. Over the precipitate thus obtained pour a warm solution of 16 per cent. ammonium-alum and 8 per cent. pure potassium cyanide, and boil the whole in a closed iron vessel for 30 minutes. The proper proportions for the solutions are as follows: *First alum solution*: Ammonium-alum 4 lbs., water 10 quarts. *Pearl-ash solution*: Pearl-ash 4 lbs., warm water 10 quarts, ammonium carbonate  $4\frac{1}{2}$  to  $5\frac{1}{2}$  drachms. *Second alum solution*: Ammonium-alum 8 lbs., warm water 25 quarts, potassium cyanide 4 lbs., then add 20 quarts of water and about 4 lbs. more of potassium cyanide, and let the whole boil for about  $\frac{1}{4}$  hour. The filtered solution is then ready for use as the electrolytic bath. As anodes perforated aluminium plates are used, which can be raised and lowered. The cathodes receive the deposit. The bath is maintained at a temperature of between  $80^{\circ}$  and  $149^{\circ}$  F. By adding pieces of other metals, such as gold, silver, nickel, copper, etc., to the aluminium anodes, the color of the deposit may be somewhat changed. If the deposit shows a gray coloration it is made lustrous by dipping in a solution of caustic soda, which also prevents oxidation.

*Electro-depositions upon aluminium.*—The electro-deposition of other metals upon aluminium presents many difficulties which are chiefly due to the behavior of this metal in the plating baths. The deposits to be sure are formed, but they possess no adherence, and especially baths containing potassium cyanide yield the worst results in consequence of the effect of alkaline solutions upon the basis-metal. Since the production of aluminium has so largely increased, and a great number of articles of luxury and for practical use are now made of this metal, the need of decorating such articles by electro-plating or covering them entirely with other metals has been felt, since the color of aluminium is by no means a sympathetic one. Look into a show window where aluminium articles are

exposed—nothing but gray in gray. Offended, the eye of the observer turns away, and seeks a more agreeable resting place.

Aluminium behaves so differently from other metals towards the cleansing agents usually used that different methods from those previously described have to be employed in preparing it for plating. Nitric acid has almost no effect on aluminium, and pickle just as little; but, on the other hand, the metal is attacked by concentrated hydrochloric acid, dilute hydrofluoric acid, and especially by alkaline lyes. Hence if polished articles of aluminium are to be prepared for plating, alkaline lyes will have to be avoided in freeing them from grease, it being best to use only benzine for the purpose. Unpolished articles may without hesitation be freed from grease with caustic potash or soda lye, and for the production of a dead white surface be for a short time pickled in dilute hydrofluoric acid, and then thoroughly rinsed in running water. For producing an electro-deposit upon aluminium it has been considered advisable to first copper the metal, and the Aluminium Gesellschaft of Neuhausen recommends for this purpose a solution of nitrate of copper. But the adherence of the copper proved also insufficient, because in the subsequent silvering, nickeling, etc., the deposit raised up.

The copper bath recommended by Delval, consisting of sodium pyrophosphate 3 ozs., copper sulphate (copper vitriol)  $\frac{3}{4}$  oz., sodium bisulphite  $\frac{3}{4}$  oz., water 1 quart, also proved unreliable.

According to another patented process, plating of aluminium is claimed to be effected successfully, and without defect, by lightly coating the metal with silver amalgam by boiling in a silver bath compounded with potassium mercury cyanide. However, this treatment did not always yield reliable results.

According to Villon, articles of aluminium are to be immersed for one hour in a bath consisting of glycerin  $5\frac{1}{4}$  ozs., zinc cyanide 0.88 oz., zinc iodide 0.88 oz., and then heated to a red heat. When cold, they are washed with a hard brush

and water, and brought into the gold or silver bath. The success of this process seems also questionable.

The best and most reliable process is without doubt the one patented, in 1893, by Prof. Nees. It consists in first immersing the aluminium articles previously freed from grease in caustic soda lye until the action of the lye upon the metal is recognized by gas bubbles rising to the surface. The articles without being previously rinsed are then for a few minutes immersed in a solution of 77 troy grains of chloride of mercury, rinsed, again brought into the caustic soda lye, and then, without rinsing, suspended in the silver bath. The deposit of silver thus obtained adheres very firmly, and can be scratch-brushed and polished with the steel without raising up. It can also be directly gilded, brassed, or, after previous coppering in the potassium cyanide copper bath, provided with a heavy deposit of nickel and polished upon polishing wheels.

The Mannesmann Pipe Works, Germany, produce durable electro-deposits by brushing the aluminium with solutions of sulphide of gold and sulphide of silver in balsam of sulphur\* and volatile oils, and burning in the metals in a muffle, under exclusion of the air, at 840° to 930° F. Thin layers of metal which are separated adhere firmly to the aluminium, and are then provided with any electro-deposit desired. According to a process patented by the same corporation the articles are provided with a firmly adhering(?) film of zinc by immersing them in boiling solution of zinc dust in caustic soda, and are then electro-plated.

\* Solution of sulphur in linseed oil.



## CHAPTER XIV.

### GALVANOPLASTY (REPRODUCTION).

By galvanoplasty proper is understood the production, with the assistance of the electric current, of copies of articles of various kinds, true to nature, and of sufficient thickness to form a resisting body, which may be detached from the object serving as a mould.

Copper is the most suitable metal for galvanoplastic processes, that which is precipitated by electrolysis showing the following valuable properties. It may be precipitated chemically pure, and in this state is less subject to change than ordinary commercial copper, or the copper alloys in general use, its tensile strength being 20 per cent. greater than that of smelted copper. Its hardness is also greater, while its specific gravity (18.85) lies between that of cast and rolled copper.

The physical properties of copper deposited by electrolysis are dependent on the condition of the bath, as well as on the intensity and tension of the current.

The bath used for depositing copper is in all cases a solution of blue vitriol. Smee proved by experiments that, with as intense a current strength as possible without the evolution of hydrogen, the copper is obtained as a tenacious, fine-grained deposit. But when the current-strength is so intense that hydrogen is liberated, copper in a sandy, pulverulent form is obtained, and in a coarsely crystalline form when the current-strength is very slight.

At a more recent period, Hübl instituted a series of systematic experiments for the determination of the conditions under which deposits with different physical properties are obtained. Hübl worked with 5 per cent. neutral, and 5 per

cent. acid, solutions of copper, as well as with 20 per cent. neutral, and 20 per cent. acid, solutions. The neutral solutions were prepared by boiling blue vitriol solution with carbonate of copper in excess, and the acid solutions by adding 2 per cent. of sulphuric acid of 66° B $\acute{e}$ . The result was that in the neutral 5 per cent. solutions less brittle deposits were obtained with a slight current-density than in a more concentrated solution, though the appearance of the deposits was the same. The experiments with acidulated baths confirmed the fact that free sulphuric acid promotes the formation of very fine-grained deposits even with very slight current-densities, and it would seem that the brittleness of copper deposited from acid baths is influenced less by the concentration than by the current-density used.

The process used in galvanoplasty may be arranged in two classes, viz., the *deposition of copper with, or without, the use of external sources of current*, the first comprising galvanoplastic deposits produced by means of the *single-cell apparatus*, and the other those by the battery, thermo-electric pile, dynamo or accumulator.

### 1. *Galvanoplastic Deposition in the Cell Apparatus.*

The cell apparatus consists of a vessel containing blue vitriol solution kept saturated by a few crystals of blue vitriol placed in a muslin bag or a small perforated box of wood, stoneware, etc. In this vessel are placed round or square porous clay cells (diaphragms) which contain dilute sulphuric acid and a zinc plate, the zinc plates being connected with each other and with the objects to be moulded—which may be either metallic or made conductive by graphite—by copper wire or copper rods. The objects to be moulded play the same role as the copper electrode in a Daniell element, and the cell apparatus is but a species of Daniell element in which the internal, instead of the external, current is utilized.

As soon as the circuit is closed by the contact of the objects to be moulded with the zinc of the porous cell, the electrolytic

process begins. The zinc is oxidized by the oxygen, and with the sulphuric acid forms zinc sulphate (white vitriol), while the copper is reduced from the blue vitriol solution and deposited in a homogeneous layer upon the articles to be moulded.

A simple apparatus frequently used by amateurs for moulding metals, reliefs, etc., is shown in Fig. 140.

In a cylindrical vessel of glass or stoneware filled with saturated blue vitriol solution is placed a porous clay cell, and in the latter a zinc cylinder projecting about 0.039 to 0.079 inch above the porous clay cell. To the zinc is soldered a copper ring, as plainly shown in the illustration. The clay cell is filled with dilute sulphuric acid (1 acid to 30 water), to which some amalgamating salt may be suitably added. The articles to be moulded are suspended to the copper ring, care being had to have the surfaces which are to be covered near and opposite to the cell. To supplement the content of copper, small linen or sail-cloth bags filled with blue vitriol are attached to the upper edge of the vessel.

FIG. 140.

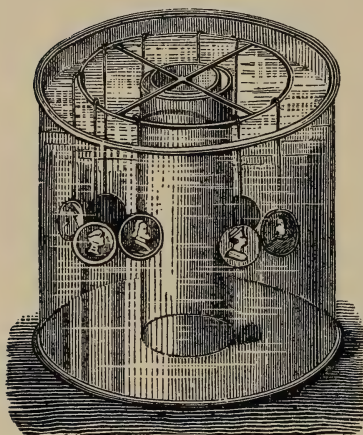
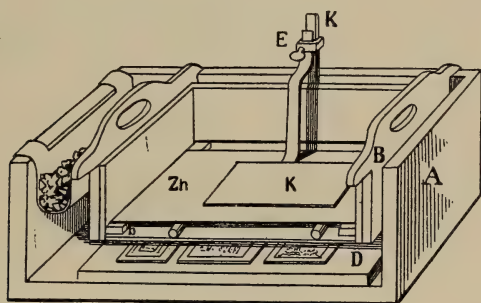


Fig. 141 shows another form of cell-apparatus which is much used in printing establishments for the production of clichés. *A* is a large box lined with gutta-percha. In this box is suspended a smaller box, *B*, the bottom of which is formed of a disk of leather or parchment. To the side of this box are nailed strips, *b*. To these strips is secured a piece of stout linen, which serves partially as a support of the zinc plate, *Zn*, and partially to prevent impurities of the zinc from falling upon the leather disk. The zinc plate is connected with the strap, *K*, which is made of thin sheet copper. In the box, *A*, lies the board, *D*, which is sufficiently weighted with strips of lead to

prevent it from floating in the fluid. To prevent the separation of copper, these lead strips are coated with a varnish made from sealing-wax or with gutta-percha. To the upper side of the board is nailed the copper strap,  $K'$ , which is insulated as far as it touches the fluid and the board by a coating of gutta-percha. The binding screw,  $E$ , connects the two copper straps. A perforated copper sheet bent in the form of a gutter dips above in the copper solution. During the operation this copper sheet is kept filled with crystals of blue vitriol, and serves to maintain a uniform saturation of the fluid.

To produce deposits with this apparatus, the first matrice is laid upon the portion of copper strap upon the board,  $D$ . The copper strap is then connected with the conducting surface by

FIG. 141.



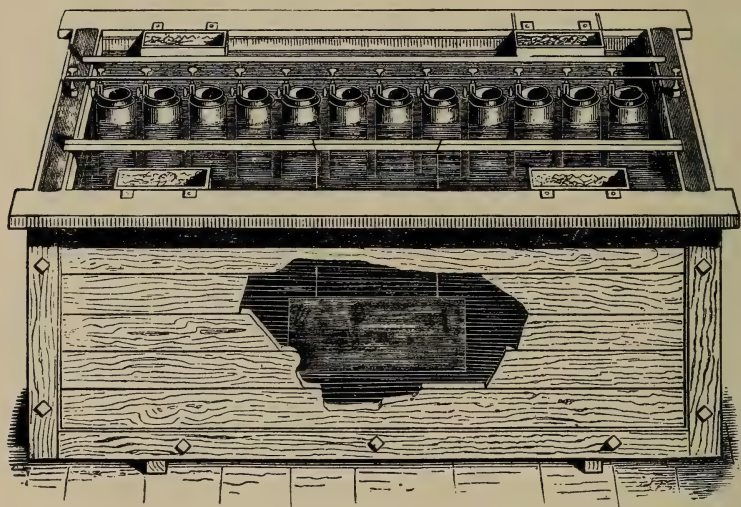
driving a brass pin through the matrice and the strap into the board. Underneath the other end of the matrice is placed a small piece of copper sheet insulated by gutta-percha, so that it projects  $\frac{1}{2}$  to  $\frac{3}{4}$  inch beneath the matrice. It is also brought in contact with the conducting surface by means of a brass pin. Upon this sheet is placed the second matrice, which is also secured with a brass pin, and so on, until all the moulds upon which the copper is to be deposited are upon the board. The surfaces of the moulds, as well as the heads of the pins, are then carefully rubbed with graphite, and the board is brought into the box filled with the vitriol solution. The box,  $B$ , with the zinc plate is then suspended in the box,



*A*, and after filling it with dilute sulphuric acid, the two copper straps are connected by the binding screw, *E*. The electric current then passes through the latter, and the pin to the surface of the first matrice, and after depositing copper upon it passes through the second pin and the small copper plate to the second matrice, and so on, effecting a uniform deposit of copper upon all conducting surfaces connected with each other.

*Large apparatus.*—To cover large surfaces, large, square tanks of stoneware, or wood, lined with lead, gutta percha, or

FIG. 142.



another substance unacted upon by the bath are used. For baths up to three feet long, stoneware vats are to be preferred.

Fig. 142 shows the *French form of cell apparatus*. In the middle of the vat, and in the direction of its length, is disposed a row of cylindrical cells, close to each other, each provided with its zinc cylinder. A thin metallic ribbon is connected with all the binding screws of the cylinder, and is in contact at its extremities with two metallic bands on the ledges of the depositing vat. The metallic rods supporting the moulds are

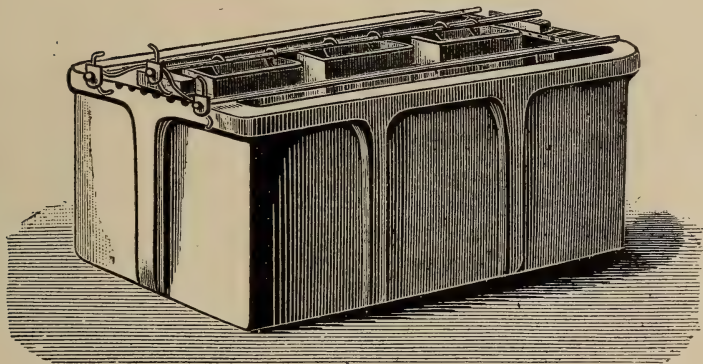
in contact with the metallic bands of the ledges, and, therefore, in connection with the zincs.

The *German form of cell apparatus* is shown in Fig. 143. It is provided with long, narrow, rectangular cells of a correspondingly greater height than the column of fluid.

Across the vat are placed three conducting rods connected with each other by binding screws and copper wire. To the centre rod, which lies over the cells, are suspended the zinc plates by means of a hook, while the two outer rods serve for the reception of the moulds.

The size of the zinc surfaces in the simple apparatus should

FIG. 143.



be about equal to that of the surfaces to be moulded, if dilute sulphuric acid (1 acid to 30 water) is to be used. For particulars see "Execution of the Galvanoplastic Deposition of Copper."

The *copper bath for the cell apparatus* consists best of a moderately saturated solution of pure blue vitriol, free from iron, in water free from lime, and should show about  $18^{\circ}$  to  $20^{\circ}$  Bé., a bath of 100 quarts requiring about 20 to 24 lbs. of blue vitriol. The following table gives the approximate content of pure crystallized blue vitriol at different degrees Bé., and at  $59^{\circ}$  F.

Degrees, Bé.	Weight by volume.	This solution contains crystallized blue vitriol.
5° .....	1.035	5 per cent.
10° .....	1.072	11 "
12° .....	1.088	13 "
15° .....	1.113	17 "
16° .....	1.121	18 "
17° .....	1.130	19 "
18° .....	1.138	20 "
19° .....	1.147	21 "
20° .....	1.157	23 "
21° .....	1.166	24 "
22° .....	1.176	25 "

While to a copper bath working with the use of an external source of current, more or less sulphuric acid is added, according to requirements, baths in the single cell apparatus do not require such addition, because a considerable quantity of the acid in the clay cell gradually penetrates by osmose into the bath, and not only of the acid alone, but also of the white vitriol solution formed, whereby the working duration of the bath is considerably reduced. Furthermore, the sulphuric acid liberated by the separation of copper from the blue vitriol finds no saturation; so that such a bath finally contains an excess of acid which for the production of good deposits must from time to time be removed, if it is not preferred to throw the bath away and make a fresh one. The simplest method of removing the excess of acid is to add to the bath pure copper carbonate as long as strong effervescence takes place, blue vitriol being thereby formed, and hence the bath at the same time strengthened. Some operators remove the excess of acid by adding to the bath whiting free from iron until no more effervescence takes place, and then filtering off from the calcium sulphate (gypsum) formed. The first-mentioned process is, however, preferable in every respect.

## 2. *Galvanoplastic Deposition by the Battery and Dynamo.*

Since it has been shown in the preceding section that a cell apparatus is to be considered as a Daniell element closed in

itself, it will not be difficult to comprehend that in economical respects no advantage is offered by the production of galvanoplastic depositions by a separate battery, because in both cases the chemical work is the same, and the zinc dissolved by the use of the Daniell or Bunsen element effects no greater quantity of copper deposit in the bath than the same quantity of zinc dissolved in the cells of the single apparatus. In other respects the use of a battery, however, offers great advantages. The employment of external sources of current requires the same arrangement as shown in Figs. 54 and 55, pp. 104 and 105; copper anodes being placed in the bath, which are connected with the anode pole of the battery.

By this arrangement, while the copper is being deposited upon the mould, the copper anodes become dissolved by the sulphuric acid set free, copper sulphate being formed, which continued action keeps the copper content of the bath quite constant. Furthermore, no foreign metallic admixtures reach the bath, as is the case in the single cell apparatus, by the white vitriol solution penetrating from the clay cell into the bath, and causing the formation of rough and brittle deposits of copper. The principal advantage, however, is that by placing a resistance board in the circuit, the current-strength can be controlled so that the deposits can be quickly covered with a strong current, and then augmented with a weaker current, and that by intelligently regulating the current-strength, deep depressions can also be covered, which is effected with difficulty in the single-cell apparatus.

#### *A. Depositions with the Battery.*

The Daniell element described on p. 38, which yields a tension of about 1 volt, is much liked for this purpose. Since the copper bath for galvanoplastic purposes requires for its decomposition an electromotive force of only 0.5 to 1 volt, it will be best for slightly depressed moulds to couple the elements for quantity (Fig. 3, p. 20), alongside of each other; and only in cases where the particular kind of moulds requires a current



of stronger tension, to couple two elements for tension one after the other, an excess of current being rendered innocuous by means of the resistance board, or by suspending larger surfaces.

Bunsen elements may, however, be used to great advantage, since the zincs of the Daniell elements become tarnished with copper, and have to be frequently cleansed if the process is not to be retarded or entirely interrupted. The Bunsen elements need only be coupled for quantity, their electromotive force being considerably greater. To be sure, the running expenses are much greater than with Daniell elements, at least when nitric acid is used for filling. All that has been said under "Electro-plating arrangements in particular," p. 97, in regard to conducting the current, the resistance boards, conducting rod, anodes, etc., is also valid for plants for the galvanoplastic deposition of copper with the battery.

#### B. *Depositions with the Dynamo.*

It is best to use dynamos capable of yielding a large quantity of current with a tension of 2, or, at the utmost,  $2\frac{1}{2}$  volts. In order to avoid repetition, the reader is referred to what has been said under "Arrangements with dynamo-electric machines," p. 115, the directions given there applying also to the galvanoplastic process. Since only in very rare cases the object-surface will be the same in all baths, it will be advisable to supply each of the baths, if several of them are worked with one dynamo, with a resistance-board and a voltmeter.

Under certain conditions, coupling the baths one after the other may be of advantage, but in this case a dynamo of a correspondingly higher tension has to be used.

*Copper baths for galvanoplastic depositions with a separate source of current.*—The directions for the composition of the bath vary very much, some authors recommending a copper solution of 18° Bé. which is brought up to 22° Bé. by the addition of pure concentrated sulphuric acid. Others again

increase the specific gravity of the bath up to  $25^{\circ}$  Bé. by the addition of sulphuric acid, while some prescribe an addition of 5 to 7 per cent. of sulphuric acid. It is difficult to give a general formula suitable for all cases, because the addition of sulphuric acid will vary according to the current-strength at disposal, the nature of the moulds, and the distance of the anodes from the objects. The object of adding sulphuric acid is, on the one hand, to render the bath more conductive and, when used in proper proportions, to make the deposit more elastic and smoother, and prevent the brittleness and coarse-grained structure which, under certain conditions, appear. When depositing with a battery, somewhat more sulphuric acid may be added to the bath than when employing the current of a dynamo. The following compositions have, in most cases, been found suitable for the reproduction of shallow as well as of deep moulds.

I. *For depositing with the dynamo.*—Blue vitriol solution of  $18^{\circ}$  Bé. 100 quarts, pure sulphuric acid of  $66^{\circ}$  Bé. 1 to  $1\frac{1}{2}$  quarts.

II. *For depositing with the battery.*—Blue vitriol solution of  $18^{\circ}$  Bé. 100 quarts, pure sulphuric acid of  $66^{\circ}$  Bé.  $1\frac{1}{2}$  to 2 quarts.

For some special uses, the composition of the bath has to be somewhat modified, which will be referred to later on. In regard to the *elasticity, strength and hardness* of galvanoplastic depositions of copper, Hübl found that copper of great toughness, but of less hardness and strength, is obtained with a current-density of 0.6–1.0 ampère from an 18 per cent. blue vitriol solution, and copper of great hardness and strength, but of little toughness, with 2 to 3 ampères, from a 20 per cent. solution.

*For copper printing-plates*, a 20 per cent. solution, compounded with 3 per cent. of sulphuric acid, and with the use of a current-density of 1.3 ampères, was found most suitable.

Many operators prefer as a bath a solution of pure blue vitriol of  $22^{\circ}$  Bé., without any addition of sulphuric acid. A

good deposit is obtained in such a bath, but a tension of 2 to  $2\frac{1}{2}$  volts is required, while acidulated baths need only  $\frac{3}{4}$  to  $1\frac{1}{2}$  volts, according to the content of acid.

Very fine deposits have also been obtained in baths consisting of a blue vitriol solution of  $21^{\circ}$  Bé., brought up to  $22^{\circ}$  by the addition of sulphuric acid. This shows that it is not necessary to stick to a fixed unlimited composition of the baths, provided it is understood how to bring the current-condition into harmony with the composition.

According to the composition of the bath, a fixed minimum and maximum current-density corresponds to it, which must not be exceeded if serviceable deposits are to be obtained. There is, however, a further difference according to whether the bath is at rest or agitated. Hübl obtained the following results :

Composition of solution.	Minimum and maximum current-density per 15.5 square inches.	
	With solution at rest. Ampères.	With solution gently agitated. Ampères.
15 per cent. blue vitriol, without sulphuric acid.....	2.6 to 3.9	3.9 to 5.2
15 per cent. blue vitriol, with 6 per cent. sulphuric acid. ....	1.5 " 2.3	2.3 " 3.0
20 per cent. blue vitriol, without sulphuric acid.....	3.4 " 5.1	5.1 " 6.8
20 per cent. blue vitriol, with 6 per cent. sulphuric acid.....	2.0 " 3.0	3.0 " 4.0

Touching the addition of sulphuric acid, it was shown that no difference in the texture of the deposit is perceptible if the addition of acid varies between 2 and 8 per cent.

The preceding table shows that a copper bath when gently agitated can stand considerably higher current-densities, and hence will work with correspondingly greater activity than a

bath at rest. In the electrolytic refining of copper it was found that for the faultless deposition of copper the bath must be maintained entirely homogeneous in all its parts. When a copper bath is at rest, and the depositing operation is in progress, the upper layers of the bath become poorer in copper than the lower, while at the same time they contain more sulphuric acid. This difference in the composition of the upper and lower layers has the disadvantage that the portions dipping into the layers richer in copper become more thickly coppered than those in the upper layers. Baths which are constantly gently agitated show less inclination to the formation of knots and other rough excrescences, and hence the current-density may be greater than with solutions at rest, the result being that deposition is effected with greater rapidity. These experiences gathered in electro-metallurgical operations on a large scale, have been advantageously applied to galvanoplasty.

Constant agitation of the copper-bath may be effected in various ways. A mechanical stirring contrivance may be provided, or agitation may be effected by blowing in air, or finally, by the flux and reflux of the copper solution.

With the use of a stirring apparatus, stirring rods of hard rubber or glass which are secured to a shaft running over the bath, swing like pendulums between the electrodes. This motion of the shaft is effected by means of leverage driven from a crank pulley. The stirring rods should not move with too great rapidity, otherwise the slime from the anodes, which settles in the bath, might be stirred up.

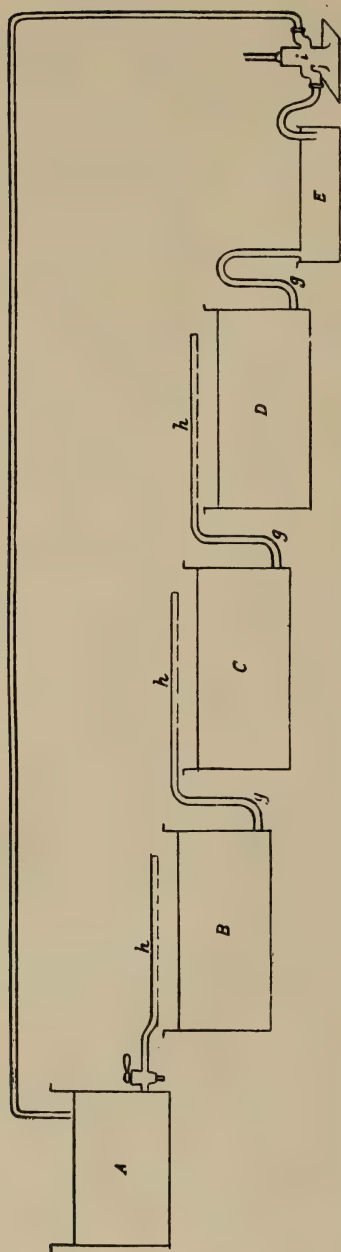
If the bath is to be agitated by blowing in air, the latter is forced in by means of a pump through perforated lead pipes arranged horizontally about two inches from the bottom of the tank.

Agitation of the bath by flux and reflux of the solution may be effected in various ways, and is especially suitable where many copper baths are in operation.

The baths are arranged in the form of steps. Near the bottom each bath is provided with a leaden outlet-pipe (Fig.



FIG. 144.



144), which terminates over the next bath over a distributing gutter, or as a perforated pipe, *h*. From the last bath the copper solution flows into a reservoir, *E*, from which it is forced by means of a hard-rubber pump, *i*, into the reservoir, *A*, placed at a higher level. From *A* it again passes through the baths *B*, *C*, and *D*. A leaden steam coil may, if necessary, be placed in *A*, to increase the temperature, if it should have become too low. Over *A* a wooden frame covered with felt may be placed; the copper solution flowing upon the frame and passing through the felt is thereby filtered.

Annealed sheets of the purest electrolytic copper are used as anodes. Impure anodes introduce other metallic constituents into the bath, and the result might be a brittle deposit. The use of old copper boiler sheets, so frequently advocated, is decidedly to be rejected.

The more impurities the anodes contain the darker the residue formed upon them will be, and this residue in time deposits as slime upon the bottoms of the tanks. Anodes of electrolytic copper also yield a residue,

which, however, is of a pale brown appearance, and consists of cuprous oxide and metallic copper. It is recommended daily to free the anodes from adhering residues by brushing, so as to decrease the collection of slime in the bath.

The anode surfaces should be at least equal to that of the moulds, and for shallow moulds the distance between them and the anodes may be from 2 to 3 inches, but for deeper moulds it must be increased.

The copper withdrawn from the bath by deposition is only partially restored, but not entirely replaced, by the anodes, and hence the content of copper will in time decrease, and the content of free acid increase. The deficiency of copper can, however, be readily replaced by suspending bags filled with blue vitriol in the bath, while too large an excess of acid is removed by the addition of copper carbonate.

However, in order not to grope in the dark in making such corrections of the bath, it is necessary to determine from time to time the composition of the copper solution as regards the content of copper and acid, for which purpose the methods described below may be used.

#### *Examination of the Acid Copper Baths.*

*Determination of Free Acid.*—The free acid is determined by titrating the copper solution with standard soda solution, congo-paper being used as an indicator. Bring by means of a pipette, 10 cubic centimeters of the copper bath into a beaker, dilute with the same quantity of distilled water, and add drop by drop from a burette standard soda solution, stirring constantly, until congo-paper is no longer colored blue, when moistened with a drop of the solution in the beaker. Since 1 cubic centimeter of standard soda solution is equal to 0.049 gramme of free sulphuric acid, the cubic centimeters of standard soda solution used multiplied by 4.9 give the number of grammes of free sulphuric acid per liter of bath.

*Volumetric determination of the content of copper according to Haën's method.*—This method is based upon the conversion of

blue vitriol and potassium iodide into copper iodide and free iodine. By determining the quantity of separated free iodine by titrating with solution of sodium hyposulphite of known content, the content of blue vitriol is found by simple calculation. The process is as follows: Bring 10 cubic centimeters of the copper bath into a measuring flask holding  $\frac{1}{10}$  liter, neutralize the free acid by the addition of dilute soda lye until a precipitate of bluish cupric hydrate, which does not disappear even with vigorous shaking, commences to separate. Now add, drop by drop, dilute sulphuric acid until the precipitate just dissolves; then fill the measuring flask up to the mark with distilled water, and mix by vigorous shaking. Of this solution bring 10 cubic centimetres by means of a pipette into a flask of 100 cubic centimetres' capacity and provided with a glass stopper; add 10 cubic centimetres of a 10 per cent. potassium iodide solution, dilute with some water, and allow the closed vessel to stand about 10 minutes. Now add from a burette, with constant stirring, a decinormal solution of sodium hyposulphite until starch-paper is no longer colored blue by a drop of the solution in the flask. Since 1 cubic centimetre of decinormal solution corresponds to 0.0249 gramme of blue vitriol ( $=0.0063$  gramme of copper), the content of blue vitriol in one liter of the solution is found by multiplying the number of cubic centimetres of decinormal solution used by 24.9. For the correctness of the result it is necessary that the copper bath should be free from iron.

*The electrolytic determination of the copper* being more simple, it is to be preferred to the volumetric method. Bring by means of the pipette 10 cubic centimetres of the copper bath into the previously weighed platinum dish, add 2 cubic centimetres of strong nitric acid, fill the dish up to within 1 centimetre of the rim with distilled water, and electrolyze with a current-strength  $ND\ 100 = 1$  ampère.

Deposition of copper is finished when a narrow strip of platinum sheet placed over the rim of the dish and dipping into the fluid shows in 10 minutes no trace of a copper deposit,

which is generally the case in  $3\frac{1}{2}$  hours. The deposit is then washed without interrupting the current, rinsed with alcohol and ether, and dried for a short time at  $212^{\circ}$  F. in the air bath. The increase in weight of the platinum dish multiplied by 100 gives the content of metallic copper in grammes per 1 liter of bath. To find the content of blue vitriol, multiply the found content of copper per liter by 3.92, or multiply the content of copper determined in 10 cubic centimeters of bath by 392.

If now the content of free acid and of the blue vitriol in the bath has been ascertained, a comparison with the contents originally present in preparing the bath will show how many grammes per liter the content of acid has increased, and how many grammes the content of copper has decreased. Then by a simple calculation it is found how much dry pure copper carbonate has to be added per liter of solution to restore the original composition. For each gramme more of sulphuric acid than originally present, 1.25 grammes of copper carbonate have to be added, and each gramme of copper carbonate increases the content of blue vitriol 2.02 grammes per liter of bath. By reference to these data the operator is enabled to calculate whether the quantity of copper carbonate added for the neutralization of the excess of free acid suffices to restore the original content of blue vitriol; or whether, and how much, blue vitriol per liter has to be added.

With the use of baths in which the solutions circulate, the additions are best made in the reservoir placed at a higher level, into which the solution constituting the bath is raised by means of a pump. The composition of such baths, connected one with the other, is the same, and a single determination of the content of copper and free sulphuric acid will suffice. However, with baths the contents of which do not circulate and are not mixed, a special determination has to be made for each bath and the calculated additions have to be made to each separate bath.

*Preparation of moulds (matrices) in plastic material.*—If a negative of the original for the production of copies is not to



be made by direct deposition upon a metallic object, the negative has to be prepared by moulding the original in a plastic mass, which on hardening will retain the forms and lines of the design to the finest hatchings. Gutta-percha, wax (stearine, etc.), plaster of Paris, glue, and a few readily fusible metals are suitable materials for this purpose.

Since the galvanoplastic process, as far as it applies to *electrotyping*, will next be considered, we first direct our attention to the preparation of moulds or matrices of gutta-percha and wax, the only materials suitable for this purpose, and which are generally used.

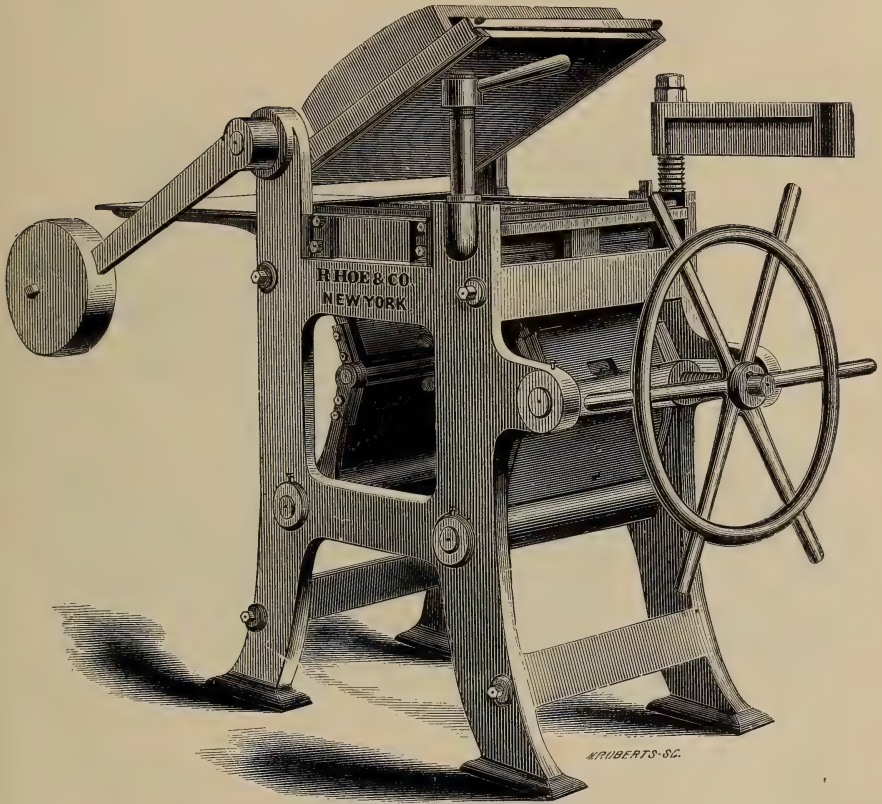
1. *Moulding in gutta-percha*.—For the reproduction of the fine lines of a wood-cut or copper-plate, pure gutta-percha freed by various cleansing processes from the woody fibres, earthy substances, etc., found in the crude product, is very suitable. Besides the requisite degree of purity, the gutta-percha should possess three other properties, viz., it must become *highly plastic* by heating, without, however, becoming *sticky*, and finally it should *rapidly harden*.

The most simple way of softening gutta-percha is to place it in water of  $176^{\circ}$  to  $194^{\circ}$  F. When thoroughly softened no hard lumps should be felt in kneading with the hands, in doing which the latter should be kept thoroughly moistened with water. A fragment corresponding to the size of the object to be moulded is then rolled into a plate about  $\frac{1}{3}$  to  $\frac{3}{4}$  inch thick. To facilitate the detachment of the mould after cooling, the surfaces of the objects to be moulded, as well as the side of the gutta-percha which is to receive the impression, should be well brushed with black lead (plumbago or graphite). The black-leaded surfaces are then placed one upon the other, and after gently pressing the gutta-percha with the hand upon the original the whole is placed in the press. To stop the further movement of the press-plate and prevent injury to the mould by too strong a pressure, small iron blocks, somewhat higher than the frame containing the object to be moulded and the gutta-percha plates, are placed on both sides of the frame.

The screw of the press is then made to act until the press-plate touches the iron blocks. Under this pressure the gutta-percha is allowed to cool and harden.

For making the impression of the form in the moulding composition, a moulding press is used which is capable of giv-

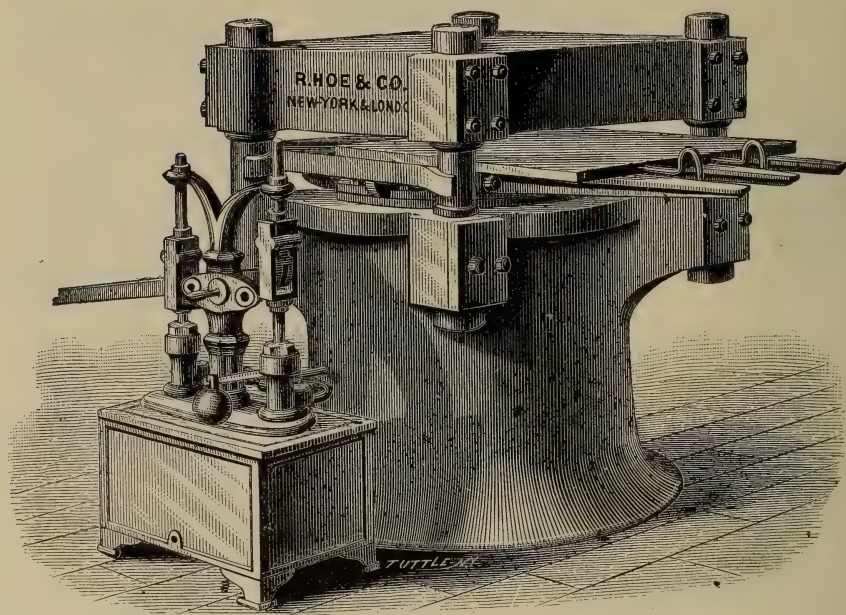
FIG. 145.



ing a gradual and powerful pressure. Fig. 145 represents a form of moulding press in common use, and known as the "toggle" press. It consists of a massive frame having a planed movable bed over which a head is swung on pivots and counterbalanced by a heavy weight, as shown, so that it can be readily

thrown up, leaving the bed exposed, the black-leaded type-form being placed on the bed. The well black-leaded case is attached by clamps to the movable head, or the form (also black-leaded) is laid face down on the case, and the head is then turned down and held in place by the swinging bar (shown turned back in the cut). All being ready, the toggle-pressure is put on by means of the hand-wheel and screw, the result being to raise the bed of the press with an enormous

FIG. 146.



pressure, causing the face of the type-form to impress itself into the exposed moulding surface.

Fig. 146 represents a form of "hydraulic press" less commonly used than that just described. It is provided with projecting rails and sliding plate, on which the form and case are arranged before being placed in the press. The pump, which is worked by hand, is supported by a frame-work on



the cistern below the cylinder, and is furnished with a graduated adjustable safety-valve to give any desired pressure.

2. *Moulding in wax (stearine).*—Beeswax is a very useful material for preparing moulds, but, like stearine, it is according to the temperature now softer and now harder, which must be taken into consideration. In the cold, pure beeswax is quite brittle and apt to become full of fissures in pressing. To decrease the brittleness certain additions are made to the wax. Urquhart recommends the following mixture, which is frequently used in England: Beeswax 85 parts by weight, Venice turpentine 13, black-lead finely pulverized 2.

According to Volkmer, a good mixture is obtained by melting together 70 parts of wax and 30 of stearine. Watt prefers a mixture consisting of 70 parts of wax, 26 of stearine, and 4 of litharge or flake-white. G. L. v. Kress recommends the following mixture: White wax 42.32 ozs., Syrian asphalt 14.11 ozs., stearine 14.11 to 21.16 ozs., tallow 10.58 ozs., graphite 1.76 ozs. First melt the asphalt over a moderate fire, then add the wax, stearine and tallow, and when these are melted, the graphite; stir until the mixture begins to congeal.

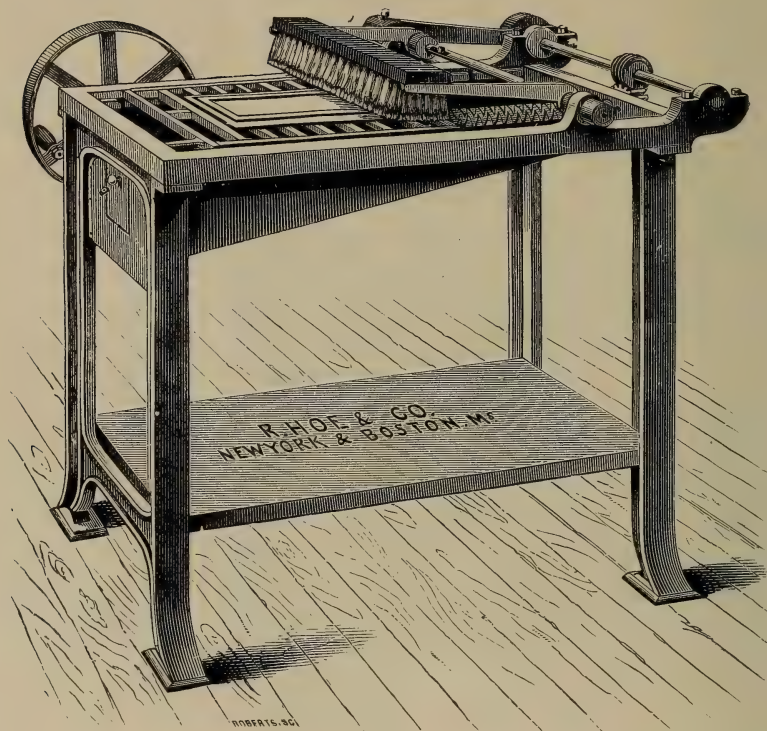
To prepare the wax mould pour the melted composition into flat metallic trays provided with loops for suspension in the bath. When the composition is nearly set remove any bubbles of air or impurities from the surface with blotting-paper. After black-leading the surface, press the original, also black-leaded, upon the composition and submit the whole to pressure until cold. When the black-leading has been carefully done there is no difficulty in detaching the original after cooling. Many operators slightly oil the surface of the original instead of black-leading.

When the mould of gutta-percha or wax has been properly made, it is thoroughly black-leaded in order to give it a conducting surface upon which the electro-deposition of the copper may take place. Black-leading must be very thorough so that the black-lead penetrates into every line and letter of the mould, otherwise the copper deposited on the surface will be



an imperfect copy of the original, and it will be useless to place the mould in the bath. The black-lead used in every stage of the electrotyping process must be of the purest description and in the most minute state of division. The best material for the purpose is prepared from the purest selected

FIG. 147.



Ceylon graphite, which is ground by rolling with heavy iron balls until it is reduced to a dead-black, impalpable powder.

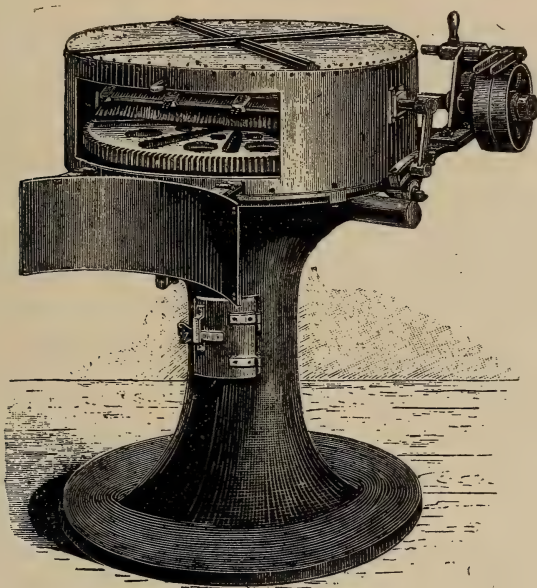
Black-leading the moulds is performed either by hand or more commonly by machines.

Fig. 147 shows one of these machines with its cover removed to exhibit its construction. It has a traveling carriage

holding one or more forms, which passes backward and forward, under a laterally vibrating brush. Beneath the machine is placed an apron which catches the powder, which is again used.

Another construction of a black-leading machine is shown in Fig. 148, the details of which will be understood without lengthy description. The moulds are placed upon the slowly revolving, horizontal wheel upon which the brush moves

FIG. 148.



rapidly up and down with a vertical, and at the same time lateral, vibrating motion. The black-leading space being closed air-tight, scattering of black-lead dust is entirely prevented, the excess of black-lead collecting in a vessel placed in the pedestal.

On account of the dirt and dust caused by the dry process of black-leading, some electrotypers prefer the wet process invented by Mr. Silas P. Knight, of New York. This process

is designed to work more quickly and neatly, producing moulds that are thinly, evenly and perfectly covered. The moulds are placed upon a shelf in a suitable receptacle, and a rotary pump forces an emulsion of graphite and water over their surfaces through a traveling fine-rose nozzle. This process is pronounced to be rapid, efficient, neat and economical.

With very deep forms of type, it is sometimes of advantage to first coat the black-leaded surface with copper, in order to obtain a uniform deposit in the bath. The process is as follows: Pour alcohol over the black-leaded form, let it run off and then place the form horizontally over a water trough. Now pour over the form blue vitriol solution of  $15^{\circ}$  to  $16^{\circ}$  B $\acute{e}$ ., dust upon it from a pepper-box some impalpably fine iron filings and brush the mixture over the whole surface, which thus becomes coated with a thin, bright, adherent film of copper. Should any portion of the surface after such treatment remain uncoppered, the operation is repeated. The excess of copper is washed off and the form, after being provided with the necessary conducting wires, is ready for the bath.

Gilt or silvered black-lead is also sometimes used for very deep forms. It is, however, cheaper to mix the black-lead with  $\frac{1}{3}$  its weight of finest white bronze powder from finely divided tin. When forms thus black-leaded are brought into the copper bath, the particles of tin become coated with copper, also causing a deposit upon the black-lead particles in contact with them.

After black-leading the workman takes one or several stout copper wires, the ends of which, after thorough cleansing, he heats for an instant, and imbeds them in the wax on the side of the mould. The surface of this wire is carefully exposed, and by way of precaution the place is rubbed with black-lead with the finger to restore the black-lead surface that may have been disturbed. Trifling as this circumstance of exposing the imbedded wire may appear, the galvanic deposit of the copper on the face of the mould would be impossible were it neglected,

as the mass of wax being a non-conductor of electricity a galvanic current could not otherwise be established. The exposure of the wire, therefore, is essential in order that the surface of the mould may be rendered properly conductive to insure the uniform deposition of copper upon it. To confine the deposit of copper where it is actually desired, and to prevent it from unnecessarily spreading over the edges of the mould, a tool called the "building iron" is heated and run over the mould so as to destroy the continuity of the black-lead surface, save where the deposit of copper is wanted.

In order that the deposition of copper may be as nearly uniform in thickness as possible over the entire surface of the mould, it becomes necessary, where a large surface is to be coated, to provide as much metallic surface as possible on which the deposit of copper may commence and spread. One method of accomplishing this, is to attach one or more pieces of metal to the wax on the edges of the mould, and connect them with the slinging wires by good metallic connections.

A very practical device in this connection is the "electric-connection gripper" of Messrs. R. Hoe & Co., of New York. This arrangement is designed to hold and sustain the moulding case, and at the same time to make an electric connection with the prepared conducting face of the mould only; consequently, leaving the metal case itself entirely out of the current, so that no copper can be deposited on it.

Gutta-percha being specifically lighter than water, moulds of this material have to be provided with a piece of heated lead stuck to the back to prevent them from floating, and to force them to occupy a perpendicular position opposite to the anodes.

The moulds are suspended in the bath in the same manner as in other galvanic processes, special care being had that their surfaces hang parallel to the anodes, so that all portion may receive a uniform deposit. Before placing the mould in the bath, pour over it, while in a horizontal position, a mixture of equal parts of alcohol and water. By this means, a uniform



moistening of the mould in the bath is attained, and the settlement of air-bubbles on it prevented.

For the production of a dense, coherent and elastic deposit in the acid-copper bath, the chief requisite is to have the current-strength in the correct proportion to the surface to be coated, this applying to deposition with the single-cell apparatus, as well as with an external source of current.

The stronger the sulphuric acid in the clay cells of the simple apparatus is, with the greater rapidity it acts upon the zinc plates, and the more quickly is the copper deposited upon the moulds. If the zinc surface of the clay cells is very large in proportion to the surface of the moulds, the deposition of copper also takes place with correspondingly greater rapidity. However, a rapid deposition of copper is to be avoided, if deposits possessing the above-mentioned desirable properties are to be obtained, because a deposit forced too much turns out incoherent, lacking in density, is frequently blistered, and, with too strong action, is even pulverulent. The color of the deposit furnishes a certain criterion for its quality; a red-brown color indicating an unsuitable deposit, and a beautiful rose color a good serviceable one.

One part of concentrated sulphuric acid of 66° Bé. to 30 of water has formerly been given as the proper proportions for the dilute acid used for filling the clay cells, provided the zinc surface be about the same as that of the moulds. If the zinc surface is smaller than that of the moulds, stronger acid may be used; but if it is larger, the acid will have to be more dilute. The correct concentration of the acid in the clay cells may be readily determined by the progressive result of the deposit and its color. Deep moulds require a stronger current, and hence acid of greater strength than shallow moulds. However, if after such deep moulds are provided with a preliminary deposit, the current proves too strong for the correct progress of the operation, its action may be weakened by either diluting the acid in the clay cells with water, or by taking out a few zinc plates, or by hanging a few copper sheets upon the object-rods, or suspending more moulds.

For the deposition of copper with a separate source of current (battery or dynamo), the same that has been said above applies as regards the current-strength, which must be brought to a suitable degree by the resistance board. The most suitable current-density for the production of a good deposit is 1.5 to 2 ampères per 15  $\frac{1}{2}$  square inches of surface of moulds for baths for depositions with a separate source of current, given on page 421, if at rest, and 2 to 3 ampères if agitated.

Since even for deeper moulds a tension of 1.5 volts suffices, if the bath is acidulated, the more powerful Bunsen elements will have to be coupled alongside one another, but two of the weaker Daniell or Lallande elements one after the other, and of such groups, as many as are required will have to be coupled alongside one another for quantity of current (see page 20), to make the active zinc surface nearly equal to that of the moulds. However, for shallow moulds coupling the separate weaker elements alongside one another is also sufficient. When the moulds are coated with copper on every side, and also the deeper portions, the current is weakened if a copper deposit of pulverulent or coarse-grained structure and of a dark color should appear on the edges of the moulds, and it is feared that the deposit upon the design or type might also turn out pulverulent. The current, however, should only be sufficiently weakened to prevent a further progress of the dark deposit on the edges towards the interior of the surface of the mould. If, however, by too strong a current the separation of a pulverulent deposit upon the design has already taken place, the deposit may generally be saved, if the fact is noticed in time, and the current correspondingly weakened, as the layers are firmly united by the coherent copper then deposited.

The current of the dynamo must also be sufficiently weakened by the resistance board in front of the bath, or by that of the machine, to guarantee the good quality of the deposit. For deeper moulds the tension for covering may amount to 1 or 1.5 volts, and for very deep and steep moulds to 1.5 or 2 volts. But when the moulds are completely covered the cur-

rent is reduced to about 0.75 volt,\* and the operation finished with this tension.

The average time required for the production of a sufficiently heavy deposit with the dynamo is from 7 to 8 hours. In this time the deposit acquires a thickness of about  $\frac{1}{3}$  millimetre (0.013 inch), which corresponds to a weight of about 25 grammes (14.11 drachms) of copper per  $15\frac{1}{2}$  square inches.

For the production of an electrotype in a very short time, baths have been recommended which are prepared with copper nitrate in place of blue vitriol, and to which has been added ammonium chloride to increase their conducting power. Independent of the fact that such baths are suitable only for very shallow moulds, the deposit obtained with them is inferior in quality to that with blue vitriol baths. Besides, by the formation of ammonia the bath becomes alkaline and turbid, and requires frequent corrections, which is certainly not desirable for regular working.

When, as is frequently the case, an electrotype has to be finished and delivered in a hurry, the work may have to be continued during the night. However, it is frequently not desirable to have the dynamo running all night, and hence recourse will have to be had either to a cell apparatus or an accumulator. With the use of a cell apparatus it is advisable first to coat the moulds rapidly with the current from the dynamo, and then to finish the deposit by suspending them in the apparatus.

In modern times, accumulators which have been described on p. 87 *et seq.*, are successfully employed for the purpose.

For the galvanoplastic deposition of copper an interruption of the process is frequently of great disadvantage, since a further deposit often adheres badly to one previously formed, the result being blisters or that the deposit peels off.

If, besides a dynamo, an accumulator is to be used, it has

\* These proportions of current refer to formulæ I. and II. given on p. 421.

first to be decided for how large a surface of deposition and for how long a time it is to be employed. From this the capacity of the accumulator, which is expressed by its work in ampère-hours is calculated. It will further be known what current in ampères and how many hours will be required for charging the accumulator. If, on the other hand, the maximum surface operated upon in the baths with the direct dynamo-current is known, the required power of the dynamo which has to be procured for deposition and occasional charging of the accumulator will be readily ascertained.

A dynamo with a tension of about 3 volts should be selected, since the charging of the accumulator requires, towards the end of the operation, a tension of 2.5 volts.

*Detaching the deposit or shell from the mould.*—When the mould has received a suitable deposit, it is taken from the bath, rinsed in water, and all edges which might obstruct the detachment of the deposit from the mould are removed with a knife. From gutta-percha moulds the deposit is gradually lifted by inserting under one corner a flat horn plate, or a thin dull brass blade, and applying a very moderate pressure. Particles of gutta-percha which may remain adherent are carefully burnt off over a flame. Wax moulds are placed in an inclined position, and a stream of hot water is poured over the copper surface, by which means the wax is sufficiently softened to allow the shell of copper to be stripped off. This may be done by taking hold of one corner of the shell and quickly lifting it as the hot water flows over it. In removing the shell care should be taken to keep it straight, as otherwise it will be difficult to back and finish it properly.

In larger establishments a cast-iron casting and melting table, such as is shown in Fig. 149, is used for wax moulds. The planed table plate is hollow, and by means of tongues cast to the plate the steam which is introduced is forced to uniformly heat the entire plate. The electros are placed upon the plate, wax side down. The wax melts and runs through stop-cocks on the side into a copper kettle with double walls

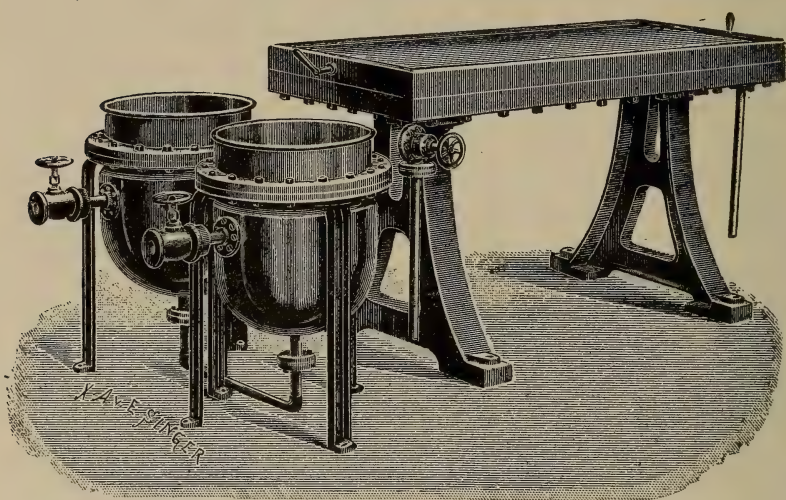


which can be heated by steam for melting the wax. The iron ledges screwed upon the table-plate are made tight with asbestos paper, so that the wax cannot run off except through the stop-cocks.

If the table is to be used for casting the wax plates, cold water, instead of steam, is allowed to circulate through the hollow table plate, whereby rapid congealing of the wax is effected.

Two such kettles are required, since the wax which has been

FIG. 149.

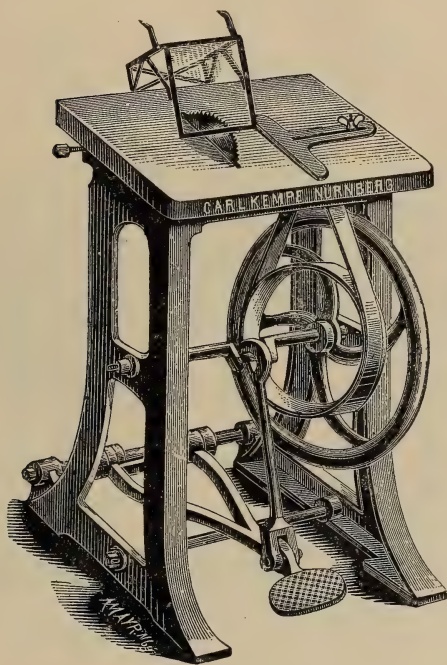


in contact with the bath has to be for several hours heated in one of the kettles to render it free from water, before it can be again used for casting. The wax freed from water is brought into the kettle and used for casting wax plates.

*Backing the deposit or shell.*—The tinning of the back of the shell is the next operation, and has for its object to strengthen the union between the shell and the backing metal. For this purpose the back of the shell is cleansed by brushing with "soldering fluid," made by allowing hydrochloric acid to take

up as much zinc as it will dissolve, and diluting with about  $\frac{1}{3}$  of water, to which some sal ammoniac is sometimes added. Then the shell, face down, is heated by laying it upon an iron soldering plate, floated on a bath of melted stereotype metal, and, when hot enough, melted solder (half lead and half tin) is poured over the back, which gives it a clean, bright, metallic covering. Or, the shell is placed downward in the backing-

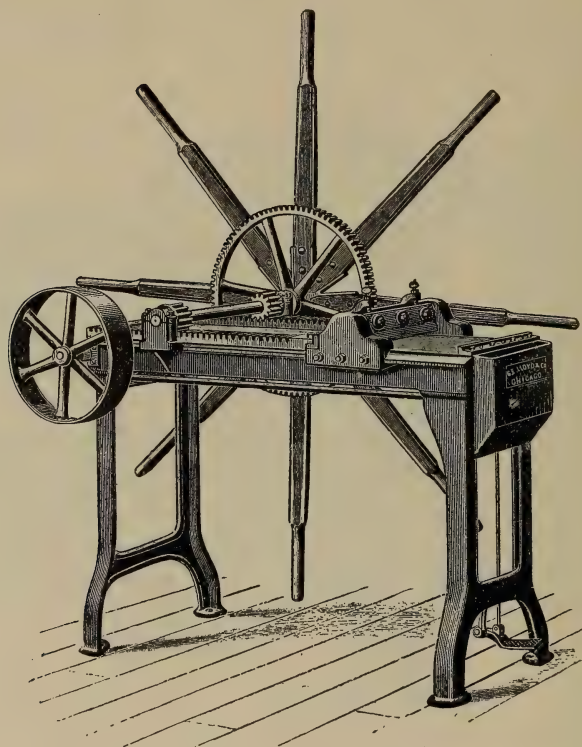
FIG. 150.



pan, brushed over the back with the soldering fluid, alloyed tinfoil spread over it, and the pan floated on the hot backing metal until the foil melts and completely covers the shell. When the foil is melted the backing pan is swung on to a leveling stand, and the melted backing metal is carefully poured on the back of the shell from an iron ladle, commencing at one of the corners and gradually running over the sur-

face until it is covered with a backing of sufficient thickness. Another method is as follows: After tinning the shell it is allowed to take the temperature of the backing metal on the floating iron plate. The plate is then removed from the melted metal, supported in a level position on a table having project-

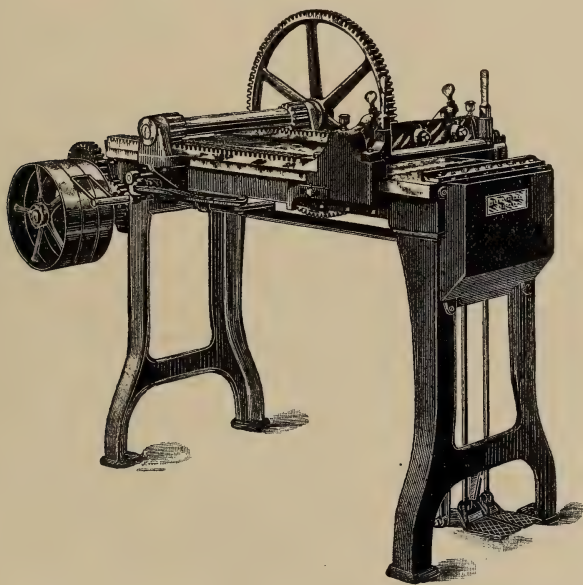
FIG. 151.



ing iron pins on which it is rested, and the melted stereotype metal is carefully ladled to the proper thickness on the back of the tinned shell. This process is called "backing." The thickness of the metal-backing is about an eighth of an inch. A good composition for backing metal consists of lead 90 parts, tin 5, and antimony 5.

*Finishing.*—For this purpose the plates go first to the saw table (Fig. 150), for the removal of the rough edges by means of a circular saw. The plates are then shaved to take off any roughness from the back and make them of even thickness. In large establishments this portion of the work, which is very laborious, is done with a power planing or shaving machine, types of which are shown in Figs. 151 and 152, Fig. 151 being a shaving machine with steam one way, and Fig. 152 one with

FIG. 152.



steam both ways. The flatness of the plates is then tested with a straight edge and any unevenness rectified by gentle blows with a polished hammer, taking care that the face be not damaged. The plate then passes to the hand-shaving machine, where the back is shaved down to the proper thickness, smooth and level. The edges of the plate are then planed down square and to a proper size, and finally the plates are mounted on wood type-high. Book-work is generally not



mounted on wood, the plates being left unmounted and finished with beveled edges, by which they are secured on suitable plate-blocks of wood or iron supplied with gripping pieces, which hold them firmly at the proper height and enable them to be properly locked up.

Finally, it remains to say a few words about the process by which a copy may be directly made from a metallic surface without the interposition of wax or gutta-percha. If the metallic surface to be moulded were free from grease and oxide, the deposit would adhere so firmly as to render its separation without injury almost impossible. Hence, the metallic original must first undergo special preparation, so as to bring it into a condition favorable to the detachment of the deposit. This is done by thoroughly rubbing the original with an oily rag, or, still better, by lightly silvering it and exposing the silvering for a few minutes to an atmosphere of sulphuretted hydrogen, whereby silver sulphide is formed, which is a good conductor, but prevents the adherence of the deposit to the original. For the purpose of silvering, free the surface of the metallic original (of brass, copper, or bronze) from grease, and pickle it by washing with dilute potassium cyanide solution (1 part potassium cyanide to 20 water). Then brush it over with a solution of  $4\frac{1}{2}$  drachms of silver nitrate and 1 oz. 6 drachms of potassium cyanide (98 per cent.) in one quart of water; or, still better, immerse the original for a few seconds in this bath, until the surface is uniformly coated with a film of silver. The production of the layer of silver sulphide is effected according to the process described later on. The negative thus obtained is also silvered, made yellow with sulphuretted hydrogen, and a deposit of copper is then made, which represents an exact copy of the original. Instead of sulphurizing the silvering with sulphuretted hydrogen, it may also be iodized by washing with dilute solution of iodine in alcohol. The washed plate, prior to bringing it into the copper bath, is for some time exposed to the light.

To prevent the separation of copper on the back of the me-

tallic original to be copied, it is coated with asphalt lacquer, which must be thoroughly dry before bringing into the bath. When the deposit of copper is of sufficient thickness, the plate is taken from the bath, rinsed in water, and dried. The edges are then trimmed off by filing or cutting to facilitate the separation of the shell from the original.

Of course only metals which are not attacked by the acid copper solution can be directly brought into the bath. Steel plates must therefore first be thickly coppered in the alkaline copper bath, and even this precaution does not always protect them from corrosion. It is therefore better to produce in a silver bath (formula I., p. 295) a copy in silver of sufficient thickness to allow of the separation of both plates. The silver plate is iodized, and from it a copy in copper is made by the galvanoplastic process. The copper plate thus obtained is an exact copy of the original, and after previous silvering, the desired number of copies may be made from it.

*Electro-etching.*—The lines produced by the ordinary process of etching actually represent, when viewed under the microscope, a continuous series of irregular depressions and small cavities, and when some depth is required they are apt to be corroded underneath, and to increase so much in width that the plates are frequently spoiled. None of these objections applies to the galvanic process of etching, which is the invention of Thomas Spencer. Each line, when viewed under the microscope, represents a perfect furrow, and is just rough enough—for instance, in the preparation of printing plates—to hold the printing ink. Lines of considerable depth may be produced without the danger of extending in width or corroding underneath. The corners of the intersection of two lines are as sharp as if the lines were engraved. A chief requisite for electro-etching is a good etching ground, since it may frequently happen that the latter may answer very well for the ordinary process, but is not capable of offering sufficient resistance to the electric current. A great advantage in electro-etching is that the solvent is always of the same strength, and,

therefore, constant in its action, and that there is no evolution of acid vapors which are injurious to the respiratory organs.

The operation of electro-etching is conducted as follows: A conducting wire is soldered with tin solder to the object, and the latter is then coated with the etching ground. The design is then traced with a graver, taking care that the tool lays bare the metal in all the lines. The object thus prepared is connected with the positive pole and suspended in the bath, while a plate of the same metal as the object is secured to the negative pole. The bath consists of a dilute acid corresponding to the metal of the object. For silver, dilute nitric acid is used; for gold and platinum, water acidulated with aqua regia; for copper, brass and zinc, water acidulated with sulphuric acid; and for tin, water acidulated with hydrochloric acid. Baths containing the metal to be etched in solution, however, work better than acids diluted with water. Thus, for gold and platinum, gold chloride and platinic chloride are used; for silver, solution of silver nitrate; for copper and brass, solution of blue vitriol; for iron and steel, solution of green vitriol, or of ammonium chloride, or a combination of both; for zinc, solution of white vitriol or of zinc chloride, etc. There are besides various metallic salts suitable for etching by themselves or in combination with the above-named salts.

As *etching ground* various compositions may be employed, it being, however, best to use, if possible, one which can be readily removed. A mixture of equal parts of asphalt and copal varnish forms a good etching ground; also a composition obtained by melting together asphalt  $2\frac{1}{2}$  parts, wax 2, rosin 1, and black pitch 2. However, the following composition, which resists 25 per cent. nitric acid, is to be preferred. It is prepared as follows: Melt yellow wax 4 parts, Syrian asphalt 4, black pitch 1, and white Burgundy pitch 1. When the mixture boils gradually add, whilst stirring constantly, 4 parts more of pulverized Syrian asphalt. Continue boiling until a sample poured upon a stone and allowed to cool breaks in bending. Then pour the mixture into cold water and

shape it into small balls, which for use are dissolved in oil of turpentine.

Since the current-strength is under perfect control, the etching may be carried to any depth desired. Some portions may be less etched than others by taking the plate from the bath, and, after washing and drying, coating the portions which are not to be further etched with lacquer, and returning the plate to the bath.

Printing plates in relief may in this manner be prepared by slightly etching the bared design of a copper-plate in the galvanoplastic copper bath, and then bringing the plate as object in contact with the negative pole, while a plate of chemically pure copper serves as anode. The deposited copper unites firmly with the rough copper of the etched plates, and after removing the etching-ground with benzine or oil of turpentine, the design appears in relief.

*Heliography.*—By this term are understood several methods of printing, in which plates of asphalt, chrome gelatine, etc., produced by exposure to light, are used. For our purposes only the method is of interest by which from the negative, produced by the action of light, a galvanoplastic reproduction—printing plates in high and low relief—in metal is made. The heliographic process invented by Pretsch and improved by Scamoni, consists in taking by photography a good negative of the engraving or other object to be reproduced, developing with green vitriol, reinforcing with pyrogallic acid and silver solution, and then fixing with sodium hyposulphite solution in the same manner as customary for photographic negatives. A further reinforcement with chloride of mercury solution then takes place until the layer appears light gray. Now wash thoroughly, and intensely blacken the light portions by pouring upon them dilute potassium cyanide solution. As in the photographic process, the solution must be applied in abundance and without stopping, as otherwise streaks and stains are formed. After washing, the plate is dried, further reinforced, and finally coated with colorless negative varnish. From this



negative a positive collodion picture is taken, which is in the same manner developed, reinforced, and fixed, the reinforcement with pyrogalllic acid being continued until the picture is quite perceptibly raised. After careful washing, pour upon the plate quite concentrated chloride of mercury solution, which has to be frequently renewed, until the picture, at first deep black, acquires a nearly white color, and the lines are perceptibly strengthened. Now wash with distilled water, next with dilute potassium iodide solution, and finally with ammoniacal water, whereby the picture acquires first a greenish, then a brown, and finally a violet-brown color. After draining, the plate may progressively be treated with solutions of platinum chloride, gold chloride, green vitriol and pyrogalllic acid, the latter exerting a solidifying effect upon the pulverulent metallic deposits. The metallic relief is now ready; the layer is slowly dried over alcohol, and the plate, when nearly cold, quickly coated with a thin rosin varnish, which, after momentary drying, remains sufficiently sticky to retain a thin layer of black lead, which is applied with a tuft of cotton. The edge of the plate is finally surrounded with wax, and, after being wired, the plate is brought into the galvanoplastic copper bath to be re-produced.

*Electro-etching in steel for the production of dies for coins, reliefs, etc.*—Below an outline of Rieder's patented process is given, it being supposed that the subject under discussion is the production of a die by means of which reliefs are to be stamped in metal plates.

The relief is first produced in a material readily worked, for instance, wood, wax, etc., and a copy of it made in plaster of Paris. The plaster of Paris plate, which is about  $\frac{1}{3}$  to  $\frac{3}{4}$  inch or more thick, is placed in a metal cylinder in such a manner that a plaster of Paris surface of 0.11 to 0.15 inch depth projects above the edge of the cylinder. This cylinder containing the plaster of Paris model is secured in a vessel containing solution of ammonium chloride and a metal spiral connected with the negative pole of the source of current. By a suitable

mechanical contrivance the vessel together with the cylinder containing the model is pressed against the steel-plate connected with the positive pole.

The process is now as follows: The porous plaster of Paris absorbs to saturation ammonium chloride solution. The steel plate first comes in contact with the highest points of relief, and the current becoming active, dissolves the steel on the point of contact. The ferrous chloride solution which is formed penetrates downward into the capillaries of the plaster of Paris so that fresh quantities of the electrolyte constantly act upon the steel plate. Etching thus progresses, and gradually every portion of the plaster of Paris model comes in contact with the steel plate, when etching is finished.

However, the practical execution of the work is not so simple as the theoretical process above described. The carbon in the steel and other admixtures, such as silicon, etc., prevent uniform etching and must, therefore, from time to time, be mechanically removed from the etching surface. For this purpose the vessel containing the electrolyte together with the model, has to be lowered, the steel plate taken from the apparatus and cleansed. It will, therefore, be readily understood that accurate etching corresponding to the metal can only take place when the principal parts, namely, the steel plate and model, after cleansing, mathematically occupy exactly the same place and position as before, so that the model presses accurately against the same parts of the steel plate as in the beginning of the etching operation.

Conjointly with Dr. Geo. Langbein & Co., Rieder has constructed an apparatus which works with such precision as to fulfill all the above mentioned conditions. Cleansing of the steel plate is effected by means of an electrically driven circular brush. For further details those interested are referred to Geo. W. Langbein & Co., who have secured by contract the sole right to this process.

*Galvanoplastic reproduction of busts, vases, etc.*—For this purpose an entirely different process of preparing the moulds than

that described for electrotyping is required, the material for moulding depending on the nature of the original. Besides gutta-percha and wax, readily fusible metals, plaster of Paris, and glue will have to be considered. If the original bears heating to about  $230^{\circ}$  F., a copy in one of the readily fusible alloys given later on may be made. If it will stand heat and pressure, it is best to mould in gutta-percha; but if neither heat nor pressure can be applied, the moulds will have to be executed in plaster of Paris or in glue. The manner of moulding and the material to be chosen furthermore depend on whether surfaces in high relief or round plastic bodies are to be copied, whether projecting portions are undercut, and whether the mould can be directly detached, or, if this is not the case, whether the original has to be dissected and moulded in separate parts.

Regarding the practice of moulding, the reader is referred to special works on that subject. Only the main points for the most frequently occurring reproductions will here be given.

Surfaces in relief and not undercut are readily moulded in an elastic mass such as gutta-percha or wax; however, undercut reliefs and especially round plastic objects mostly require a plaster-of-Paris mould and are generally dissected. The dissection, of course, is not carried further than absolutely necessary, because the separate parts must be united by a soldering seam, which requires careful work, and the seam itself must be worked over and made invisible. Hence the section should as much as possible be made through smooth surfaces, edges, etc., where the subsequent union by a soldering seam will prove least troublesome, while cutting through ornaments or through portions the accurate reproduction of which is of the utmost importance, should be avoided. Heads and busts are always executed in a core mould and in portions, unless the entire figure is to be deposited in one piece in a closed mould. The section is made either through the centre line of the head through the nose, which, however, makes the subsequent union very troublesome, if the copy is to be an exact reproduction of

the original, or the mould is divided from ear to ear, which has the disadvantage that the deepest part of the mould corresponding to the nose receives the thinnest deposit. It has, therefore, been proposed to make two cuts so that three portions are formed; one cut from one ear at the commencement of the growth of hair to the other ear; and the second cut from one ear in a downward direction below the lower jaw in the joint of the head and neck, through this joint below the chin, and then upwards to the other ear, and in front of it to where the hair begins. In bearded male heads the cut follows the contour of the beard and not the joint on the neck behind the beard.

Oil gutta-percha has the advantage of allowing moulding without any pressure of the largest shield-shaped or semi-circular objects with all undercuts, which otherwise can only be accomplished with glue. The mould can be readily detached from the original as well as from the deposit, which is of great advantage. But, on the other hand, oil gutta-percha deteriorates by frequent use, and burns to the mould when worked too hot, the result being that it is difficult to detach from the original, as well, the formation of air bubbles. However, the heat must neither be too slight, otherwise the sharpness of the impression would suffer.

Oil gutta-percha is prepared by heating in the water bath 100 parts of gutta-percha, 10 parts of olive oil and 2 parts of stearine.

The original, preferably of copper, should be free from grease. It is laid upon an iron plate and the latter heated by a flame until the original can be just for a moment retained in the hand. The oil gutta-percha, previously heated in a sand bath and thoroughly stirred, is then brought in a slow stream upon the original. After allowing the oil gutta-percha to congeal superficially, the original, together with the heating plate, is brought into cold water, where complete congealing soon takes place.

For moulding in the press or by hand with oil gutta-percha, the heated mass is poured into cold water and then kneaded to the consistency of stiff dough.



To mould round articles in gutta-percha, the softened gutta-percha is kneaded with wet hands upon the oiled original, or, in order to avoid some portions receiving a stronger pressure than others, and to insure a layer of gutta-percha of uniform thickness upon all parts, moulding may also be executed in a ring or frame of iron or zinc under a press. For the rest, all that has been previously said in regard to moulding in gutta-percha is also applicable.

The following *metallic alloys* have been proposed for the preparation of moulds:

- I. Lead 2 parts, tin 3, bismuth 5; fusible at  $212^{\circ}$  F.
- II. Lead 5, tin 3, bismuth 8; fusible at  $185^{\circ}$  F.
- III. Lead 2, tin 2, bismuth 5, mercury 1; fusible at  $158^{\circ}$  F.
- IV. Lead 5, tin 3, bismuth 5, mercury 2; fusible at  $127.5^{\circ}$  F.

The advantage of metallic moulds consists in the metal being a good conductor of electricity, in consequence of which heavy deposits of greater uniformity can be produced than with non-metallic moulds which have been made conductive by black lead. Nevertheless, they are but seldom employed, on account of the crystalline structure of the alloys and the difficulty of avoiding the presence of air bubbles. Böttger claims that a mixture of lead 8 parts, tin 3, and bismuth 8, which is fusible at  $227^{\circ}$  F., shows a less coarse-grained structure.

Fusible alloys containing mercury should not be used for taking casts of metallic objects—iron excepted—as these will amalgamate with the mercury and be injured. Moreover, copper deposits obtained upon such alloys are very brittle, which is due to the combination of the mercury with the deposited copper.

For moulding with metallic alloys place the oiled object at the bottom of a shallow vessel and pour the liquid metal upon it; or pour the liquid metal into a box, remove the layer of oxide with a piece of stout paper, and when the metal is just beginning to congeal, firmly press the object in it.

*Plaster of Paris* is used for making casts of portions from originals which are so strongly undercut that a mould consist-

ing of one piece could not be well detached from them. For taking casts from metallic coins and medals or from small plaster reliefs, it is a very convenient material. The mode of procedure is as follows: After the original model, say a medal, has been thoroughly soaped or black-leaded, wrap round the rim a piece of sufficiently stout paper or thin lead foil, and bind it in such a manner by means of sealing wax that the face of the medal is at the bottom of the receptacle thus formed. Then place the whole to a certain depth in a layer of fine sand, which prevents the escape of the semi-fluid plaster of Paris between the rim of the medal and the paper. Now mix plaster of Paris with water to a thin paste, take up a small quantity of this paste with a pencil or brush and spread it in a thin film carefully and smoothly over the face of the medal, then pour on the remainder of the paste up to a proper height and allow it to set. After a few minutes the plaster heats and solidifies. Then remove the surrounding paper, scrape off with a knife what has run between the paper and the rim of the medal, and carefully separate the plaster cast from the model. If, instead of applying the first layer with a brush, the whole of the plaster were run at once into the receptacle, there would be great risk of imprisoning air bubbles between the model and the mould, which would consequently be worthless. The mould is finally made impervious and conductive according to one of the methods to be described later on.

The moulding in plaster of Paris in portions, when casts from large plastic objects with undercut surfaces and reliefs are to be taken, is troublesome work, because each separate mould must not only be so that it can be readily separated without injury to the original, but must also fit closely to its neighbors. Hence thought and judgment are required to see of which parts separate moulds are to be made, or, in other words, in how many parts the mould is to be made. After determining on the plan of the work, the mode of procedure is as follows: Oil a portion of the object, if it consists of metal, or soap it, if of plaster of Paris, marble, wood, etc., and apply by means of a

brush a thinly-fluid paste of plaster of Paris, taking care that no air bubbles are formed by the strokes of the brush. When this thin coat is hard, continue the application of plaster of Paris with a horn spatula until the coat has acquired a thickness of  $\frac{3}{4}$  to 1 inch, and allow it to harden. Then separate the mould, and after cutting or sawing the edges square and smooth, replace it upon the portion of the original model corresponding to it. Now oil or soap the neighboring portions of the model, and at the same time the smooth edges of the first mould which come in contact with the mould now to be made, and then proceed to make the second mould in precisely the same manner as the first. When the second mould is hard, trim the edges and replace it upon the model; the same process being continued until the entire original model is reproduced in moulds fitting well together. To prevent the finished moulds from falling off, and to retain them in a firm position upon the original model, they are tied with lead wire or secured with catches of brass wire or sheet. When the moulds of the larger portion of the model, for instance, one-half of a statue, are finished, the so-called case or shell is made, *i. e.*, the backs of all the moulds are coated with a layer of plaster of Paris which holds them together. This case is best made not too thin in order to attain a better resisting power.

The entire model having been cast in the manner above described, and the moulds provided with the case, the whole is completely dried in an oven.

The next operation is to make the plaster of Paris impervious to fluids, as otherwise by the moulds absorbing the acid copper bath, copper would be deposited in the pores of the plaster and the moulds be spoiled, while the copy would turn out rough instead of having the smooth exterior of the model. To render plaster of Paris and other porous substances impervious, they are saturated with wax or stearine or covered with a coat of varnish, the latter process being generally employed for large moulds. Apply a coat of thick linseed oil varnish to the face of the mould, and, after drying, repeat the process until the

mould is thought to be sufficiently impervious. Rendering the mould impervious with wax or stearine is a better and more complete method. For this purpose cut a groove in the rim of the mould, place in the groove a brass wire and twist the ends, which must be long enough to hold the mould by. The mould, having been previously dried, is then dipped into a bath of wax or stearine kept at a temperature of from  $180^{\circ}$  to  $212^{\circ}$  F., and a number of air bubbles will escape from the mould to the surface. When the production of air bubbles is considerably diminished, remove the mould from the bath, and lay it face up in a drying oven, whereby the melting wax in consequence of its gravity oozes down, and the face of the mould is freed from an excess of wax. Whenever possible, submerging the entire mould should be avoided and the operation be conducted as follows: Place the heated mould in a vat filled with melted wax or stearine, so that the face does not come in contact with the wax, but absorbs wax by capillarity from the back.

The moulds thus coated with varnish or saturated with wax are now made conductive with black-lead, the operation being the same as that mentioned on p. 432. For many undercut or deep portions black-leading is, however, not sufficient, and recourse must be had to making the moulds conductive or *metallizing* them *by the wet way*.

*Metallization by the wet way.*—This method consists in the deposition of certain metallic salts upon the moulds and their reduction to metal or conversion to conductive sulphur combinations. The process in general use is as follows: Apply with a brush upon the mould a not too concentrated solution of silver nitrate in a mixture of equal parts of distilled water and 90 per cent. alcohol. When the coat is dry expose it in a closed box to an atmosphere of sulphuretted hydrogen. The latter converts the silver nitrate into silver sulphide, which is a good conductor of the current. For the production of the sulphuretted hydrogen, place in the box, which contains the mould to be metallized, a porcelain plate or dish filled with dilute sulphuric acid (1 acid to 8 water), and add five or six



pieces of iron pyrites the size of a hazel-nut. The development of the gas begins immediately, and the box should be closed with a well-fitting cover to prevent inhaling the poisonous gas; if possible, the work should be done in the open air or under a well-drawing chimney. The formation of the layer of silver sulphide requires but a few minutes, and if not many moulds have to be successively treated, the acid is poured off from the iron pyrites and clean water poured upon the latter so as not to cause useless development of gas.

It has also been recommended to decompose the silver salt by vapors of phosphorus and to convert it into silver phosphide, a solution of phosphorus in bisulphide of carbon being used for the purpose. The layer of silver salt is moistened with the solution or exposed to its vapors. This method possesses, however, no advantage over the preceding, because, on the one hand, the phosphorous solution takes fire spontaneously, and, on the other, the odor of the bisulphide of carbon is still more offensive than that of sulphuretted hydrogen.

A somewhat *modified method* is given by Parkes as follows: Three solutions, A, B, C, are required. Solution A is prepared by dissolving 0.5 part of caoutchouc cut up in fine pieces in 10 parts of bisulphide of carbon and adding 4 parts of melted wax; stir thoroughly, then add a solution of 5 parts of phosphorus in 60 of bisulphide of carbon together with 5 of oil of turpentine and 4 of pulverized asphalt; then thoroughly shake this mixture, A. Solution B consists of 2 parts by weight of silver nitrate in 600 of water; and solution C of 10 parts of gold chloride in 600 of water. The mould to be metallized is first provided with wires and then brushed over with, or immersed in, solution A, and after draining off, dried. The dry mould is then poured over with the silver solution (B) and suspended free for a few minutes until the surface shows a dark lustre. It is then rinsed in water and treated in the same manner with the chloride of gold solution (C), whereby it acquires a yellowish tone, when, after drying, it is sufficiently prepared for the reception of the deposit. Care must be taken in preparing solu

tion A, as the bisulphide of carbon containing phosphorus readily takes fire.

*Another method is as follows :* Dissolve 5 parts by weight of wax in 5 of warm oil of turpentine, and add to the solution a mixture of 5 parts by weight of phosphorus, 1 of gutta-percha, 5 of asphalt, in 120 of bisulphide of carbon. When both are thoroughly mixed, add to the whole a solution of 4 parts by weight of gun cotton in 60 of alcohol and 60 of ether, and after thoroughly shaking allow to settle. The next day pour off the clear solution from the sediment, when the solution can at once be used. It is especially well adapted for coppering parts of plants, leaves, flowers, etc.

*Another method of metallization is as follows :* Immerse the leaves, etc., in iodized collodion composed of 40 per cent. alcohol 40 cubic centimeters, ether 60 cubic centimeters, potassium iodide 1 gramme, gun cotton 1 gramme.

Allow the leaves, etc., to dry so that a firmly adhering layer is formed. Then immerse them in a solution of 10 parts by weight of silver nitrate in 100 of water, whereby a layer of silver iodide is formed. Now expose the article thus treated for some time to the light, and then immerse it in the reducing fluid consisting of water 500 parts by weight, green vitriol 25, and acetic acid of 1.04 specific gravity 2.5. The reduction of silver now progresses rapidly and the articles are ready for coppering. In employing this process it must not be forgotten that the layer of collodion will not stand rough usage and, hence, injury to it by touching with the hands and careless placing of the conducting wire have to be avoided. By operating with due care, the results are very satisfactory and sure. Instead of the iodized collodion, a mixture of equal parts of white of egg and saturated solution of common salt may be used, the remainder of the process being the same as above described.

*Metallization by metallic powders.*—In some cases metallization by metallic powders is to be preferred to black-leading or metallizing by the wet way. Metallic or bronze powders are metals in a state of exceedingly fine powder, of which, for gal-

vanoplastic purposes, pure copper and brass powders only are of interest. Since such metallic powders adhere badly to waxed surfaces, the mould must be provided with a well-drying coat of lacquer, upon which, before it is completely dry, the powder is scattered or sifted. When the lacquer is hard a smooth surface is produced by going over the mould with a soft brush dipped in the metallic powder, an excess being removed by a thin jet of water.

*Lenoir's process—Galvanoplastic method for originals in high relief.*—Lenoir's method for reproducing statues in a manner approaches in principle to that of the foundry. He begins by making with gutta-percha a mould in several pieces, which are united together so as to form a perfect hollow mould of the original. This having been done, cover all the parts carefully with black lead. Make a skeleton with platinum wire, following the general outline of the model, but smaller than the mould, since it must be suspended in it without any point of contact. If the skeleton thus prepared is enclosed in the metallized gutta-percha mould, and the whole immersed in the galvanoplastic bath, it will be sufficient to connect the inner surface of the mould with the negative pole of the battery, and the skeleton of platinum wires (which should have no points of contact with the metallized surfaces of the mould) with the positive pole, in order to decompose the solution of sulphate of copper which fills the mould. When the metallic deposit has reached the proper thickness, the gutta-percha mould is removed by any convenient process, and a faithful copy of the original will be produced. Lead wires may be substituted for the expensive platinum wires. This method requires a knowledge of the moulder's art, so that good results can only be obtained by an experienced hand.

*Gelatine moulds.*—Under certain conditions the elasticity of gelatine allows of the possibility of its removal from undercut or highly-wrought portions of the model, when it reassumes the shape and position it had before removal therefrom. But gelatine requires that the deposit shall be made rapidly, other-

wise it will swell and be partially dissolved by too long an immersion in the copper bath.

To make a good gelatine mould, proceed as follows: Allow white gelatine (cabinet-maker's glue) to swell for about 24 hours in cold water, then drain off the water, and heat the swollen mass in a water bath until completely dissolved. Compound the glue solution with pure glycerine in the proportion of 5 to 10 cubic centimetres (0.24 to 0.3 cubic inch) of glycerine to 30 grammes (1.05 ozs.) of gelatine, which prevents the gelatine from shrinking in cooling. When somewhat cooled off, apply the gelatine to the oiled original, which must be surrounded with a rim of plaster of Paris or wax, to prevent the gelatine from running off; when cold, lift the gelatine mould from the model. Before metallizing and suspending in the copper bath, the mould has to be prepared to resist the action of the latter, as otherwise it would at once swell and be partially dissolved before being covered with the deposit. This is effected by placing the mould in a highly concentrated solution of tannin, which possesses the property of making gelatine insoluble.

Brandley gives the following directions for preparing gelatine solution with an addition of tannin, which renders the moulds impervious to water: Dissolve 20 parts of the best gelatine in 100 of hot water, add  $\frac{1}{2}$  part of tannic acid and the same quantity of rock candy, then mix the whole thoroughly, and pour it upon the model.

The same end is reached by making a mould with gelatine alone, then pouring an aqueous solution of 10 per cent. of potassium dichromate upon it, and, after draining, exposing the mould to the action of the sun.

*Another method is as follows:* Beat into a quart of distilled water the whites of two eggs, filter, and cover with this liquid the entire surface of the gelatine mould. After drying, operate with the solution of potassium dichromate as in the preceding. By solar action the coating impregnated with dichromate is rendered insoluble.



The mould must finally be metallized and, when in the bath, submitted to a strong current at the beginning. When the entire surface is covered with the copper deposit, and when swelling is no longer to be feared, a weaker current may be used.

Below a few *special uses of galvanoplasty* will be briefly described :

*Nature printing*, so named by Mr. v. Auer, Director of the Imperial Printing Office at Vienna, has for its object the galvanoplastic reproduction of leaves and other similar bodies. The leaf is placed between two plates, one of polished steel, the other of soft lead, and is then passed between rollers, which exert a considerable pressure. The leaf thus imparts an exact impression of itself and of all its veins and markings to the lead, and this impression may be electrotyped, and the copper plate produced used for printing in the ordinary way. Instead of taking the impression in lead, it is advisable to use gutta-percha or wax for delicate objects, which should previously be black-leaded or oiled. In the same manner galvanoplastic copies of laces, etc., may be obtained.

The process used by Philipp for *coating laces and tissues* with copper and then silvering or gilding, belongs rather to electroplating than to galvanoplasty. The tissue is saturated with melted wax, and after removing the excess with blotting paper it is made conductive by black-leading with a brush. It is, however, preferable to metallize such delicate objects by the wet way, Parke's method being especially suitable for the purpose, and also a treatment with weak solution of silver nitrate and pyrogallic acid frequently alternated.

Elmore produces copper tubes by galvanoplastic deposition by allowing the metallic core-bar to revolve slowly between the anodes, while a polishing steel is by means of a mechanical contrivance carried with strong pressure over the deposit, whereby the latter is made dense and any roughness removed.

It would seem that the process for the production of copper tubes, profiled hollow copper bodies, etc., patented by Ignaz

Klein, is better than Elmore's method. The black-leaded or metallic core-bars are allowed to roll to and fro upon smooth or profiled plates, the so-called milling plates, or the core-bars are concentrically arranged around a cylindrical anode and allowed with pressure to roll on an exterior round milling surface. According to this method, the space in the baths can be better utilized than in the Elmore process, and the deposit shows excellent properties as regards uniform density and power of resistance.

*Corvin's niello.*—Corvin has invented a process of producing inlaid work by galvanoplasty, which has been patented, and is the exclusive property of J. P. Kayser & Son, of Crefeld. The process is as follows: A matrice of metal whose surface is finely polished is first made. This matrix may be used for the production of numerous duplicates of the same kind of object. The incrustations (mother-of-pearl, glass, ivory, amber, etc.), are then shaped by means of a saw, files and other tools, to the form corresponding to that which they are to occupy in the design. The side of the incrustation which is laid upon the matrice is, as a rule, smooth. The shaped incrustations, smooth side down, are pasted on to the parts of the model they are to occupy in the design. The latter being thus produced, the backs of the non-metallic laminæ are metallized, and the portions of the metallic plate left free are slightly oiled. By now placing the matrice thus prepared in the galvanoplastic bath, the copper is deposited, not only upon the metallic matrice, but also upon the back of the inlaid pieces, the latter being firmly inclosed by the deposited metal. When the deposited metal has acquired the desired thickness, it is detached from the matrice, and incrustations with the right side polished are thus obtained. The laminæ are more accurately and evenly laid in than would be possible by the most skilled hand-work.

*Grasses, leaves, flowers, etc.*, may be coated with copper and then silvered, gilded, or platinized, by first drying them, and, after giving them a certain elasticity by placing in glycerine, metallizing them by Parkes's or some other method.

*Plates for the production of imitations of leather* are now frequently prepared. The demand for alligator and similar leathers is at the present time greater than the supply, and, therefore, imitations are made by pressing ox-leather, the plate being prepared by galvanoplasty, as follows: A large piece of the natural skin or leather is made impervious to the bath by repeated coatings with lacquer, and, when, completely dry, secured with asphalt lacquer to a copper or brass plate. The leather is then black-leaded, and, after being made conductive by copper wire or small lead plates, brought into the copper bath. When the copper deposit has acquired the desired thickness, the plate is further strengthened by backing with stereotype metal.

*To coat wood, etc., with a galvanoplastic deposit of copper.*—The absolutely dry objects are first immersed in melted wax, paraffine, or ceresine, and when thoroughly impregnated taken out and, after draining off, allowed to cool. As the impregnating material contracts in cooling, the surface of the object is thereby freed from an excess of it. For this reason the material used for impregnating should not be made hotter than absolutely necessary, because the hotter it is the stronger the contraction or shrinkage. However, as by this contraction the edges and portions of the surface may become denuded of impregnating material, and thus be liable to be attacked by the acid copper bath, it is advisable to coat the objects, after cooling, with an acid-resisting gutta-percha lacquer prepared by dissolving 5 to 10 parts, by weight of gutta-percha cuttings in a mixture of 50 parts each of benzine and chloroform. Keep the solution in a wide-mouthed glass bottle provided with a well-fitting cork, and apply it with a brush. The solution being very inflammable, it should not be used near an open flame.

*Wooden handles of surgical instruments, etc.,* may be protected from the attacks of the acid copper bath by coating them with a solution of wax or paraffine in ether, the latter after evaporating leaving a thin layer of wax upon the object.

The articles thus prepared are black-leaded or metallized by Parkes's or one of the methods previously given, and brought into the copper bath.

*The mercury vessels of thermometers* for vacuum and distilling apparatus are surrounded by a thick copper deposit to protect them from injury by mechanical force. The metallization of *glass, porcelain, clay, terra-cotta, etc.*, is effected in the same manner as above described.

*Porcelain, pottery, stone-ware, etc.*, are provided with a galvanoplastic deposit of copper, according to a patent granted to Utzschneider & Co., by first coating the articles with a mixture of litharge and varnish. After drying, the litharge is rubbed on and the articles coppered in the galvanoplastic bath. It is claimed that the deposit of copper can be further provided with a deposit of any desired metal. The success of this process would seem doubtful.

According to another method which is thoroughly reliable, the article is provided with a conducting layer by brushing it with solution of gold chloride or platinum chloride in sulphuric ether mixed with balsam of sulphur or oil of turpentine in which sulphur has been dissolved. After heating slightly, another heavier layer is applied with a brush. The article is then heated in the muffle until a lustrous metallic layer is formed, which is suitable, without further preparation, for coppering. Upon this layer of metal a galvanoplastic deposit of silver of any desired thickness may also be produced so that the deposit appears in relief.

*Galvano-plasty in iron (steel).* Under "Deposition of Iron," the galvano-plastic production of heavy detachable deposits of iron has already been referred to.

Serviceable iron electros were first produced about 1870, by Klein, of St. Petersburg, and used for printing Russian bank notes. Their preparation was, and is still, very troublesome, success depending on the fulfillment of many conditions, so that, notwithstanding continued experiments and the expense of much labor, the former expectation of entirely sup-



planting electrotypes in copper by clichés in steel has thus far not been realized.

The bath used by Klein, and still employed for this purpose, consists of a 10 per cent. solution of a mixture of equal parts of ferrous sulphate (green vitriol) and magnesium sulphate (Epsom salt). The solution has a specific gravity of 1.05. To obtain successfully a serviceable electro from an original, for instance from a copper plate, which should previously be silvered and coated with a thin layer of silver sulphide by means of sulphuretted hydrogen, the following conditions have to be fulfilled, according to Klein's statement: The bath must be kept absolutely neutral, which is effected by suspending in it linen bags filled with magnesium carbonate, and the current-strength must be so regulated that absolutely no evolution of hydrogen is perceptible on the anodes. Further, the plates are every half hour to be taken from the bath and rinsed with a powerful jet of water to remove any adhering gas-bubbles. Care must be taken during this process that the plates do not become dry, since fresh layers do not adhere well upon places which have become dry.

It may here be mentioned that Lenz found a not inconsiderable content of hydrogen in iron deposits, and also carbonic acid, carbonic oxide, and nitrogen in varying quantities. However, examinations made by Dr. Geo. Langbein established positively only a content of hydrogen, and it would seem that this hydrogen which is absorbed and tenaciously retained by the deposit is the cause of all the difficulties encountered in the production of heavy iron deposits.

If, however, the occlusion of hydrogen is regarded as the cause of the mischief, ways and means to counteract it as much as possible may be found in the fact that iron deposited with greater current-density is more brittle, shows a greater tendency to peel off in the bath, and contains a larger quantity of hydrogen than a deposit produced with slighter current-density.

In this respect experience gained in the electrolytic refining of copper shows us the way in so far that for the production

of heavy deposits of iron, the bath must be kept in constant, vigorous agitation, to remove, on the one hand, layers of fluid poorer in metal from the cathode, and, on the other, to force, by the agitation, the gas bubbles adhering to the cathode to escape. Further, deposition must be effected with so slight a current-density that no evolution of hydrogen is perceptible on the cathode, and a current-density of 0.25 ampère may be designated as the maximum per  $15\frac{1}{2}$  square inches, with which heavy deposits of iron can be produced.

To counteract the spoiling of the deposits, further precautionary measures are, however, necessary, especially heating the electrolyte and from time to time interrupting the current. In heated baths the escape of the gas is facilitated, especially when the electrolyte is agitated, and hence adhering gas bubbles cannot remain long in one place. A constantly-repeated interruption of the current is of advantage and effective because metallic parts covered with a minimum quantity of hydrogen cannot be coated with a fresh deposit until the hydrogen is removed by the agitation of the heated electrolyte. Hence the interruption of the process of deposition would give opportunity and time for the removal of the gas molecules before further deposition takes place, and without a knowledge of the more intimate processes, Klein succeeded in effecting the interruption of the deposit, by taking the plates at short intervals from the bath and removing the adhering gas by a powerful jet of water.

With the present state of galvanoplasty it is not necessary to follow Klein's primitive method, and it will be more practical to provide the positive conducting rod of the bath with a contrivance which mechanically effects the interruption of the current. Suppose upon such a metallic conducting rod is mounted a copper or brass wheel, which is secured to a pulley and revolves around the conducting rod, and half of the periphery of which is insulated, and that upon the rod drags a metallic brush which effects the transmission of the positive current. Now, it will be seen that while the contact-wheel is revolving,

current is introduced only one-half the time and not during the other half, and that by the rapidity of revolution of the contact-wheel, the number of interruptions of the current can be varied at will.

There can no longer be any doubt that iron electros will in time be produced with the same surety as copper electros, and that, in additions to the above-mentioned conditions, which have to be complied with, others will be found which may possibly assure success in a still better manner.

It is well known that electrolytically deposited iron possesses great hardness, and that such deposits well deserve the name of steel deposits, their hardness being greater than that of iron, and approaching that of steel. This phenomenon cannot be explained otherwise than by the hydrogen absorbed by the deposit. Hence, it will be seen that, on the one hand, this absorption of hydrogen has an injurious effect upon the separation of iron, while, on the other, it imparts to the deposits the most valuable property of great hardness. It would seem that the quantities of iron first deposited upon the mould are, and can be, richer in hydrogen in order to impart to the printing surface the utmost possible hardness. However, in further strengthening and augmenting the deposit, our efforts must be directed, by the reduction of the current, to deposit strengthening layers as free from hydrogen as possible.

The question now arises, whether it is of greater advantage to steel a copper electro in order to increase its power of resistance, or whether it is better to produce an iron electro, and to strengthen its back in the acid copper bath. If the above expressed view that the layers of iron first deposited are richer in hydrogen, and therefore harder, is correct, the preference must be given to iron electros, because with steeled copper electros, the softer layers are exposed to wear, while the harder layers lie upon the copper plate. The reverse is the case with an iron electro, the first deposit, rich in hydrogen, forming the printing face.

However, on the other hand, steeled copper electros have

the advantage that, when worn, the old deposit of iron can be readily removed by dilute sulphuric acid, and the electros re-steeped, while worn iron electros have to be renewed.

*Galvanoplasty in nickel.*—Though by the electro-deposition of nickel, electrotypes are rendered fit for printing with metallic colors, which attack copper, and their power of resisting wear is increased, the latter advantage can to the fullest extent be obtained only by a thick deposit. However, this always alters the design somewhat, especially the fine hatchings, this being the reason why in nickel-plating electrotypes a deposit of medium thickness is, as a rule, not exceeded. If a hard nickel surface is desired, without injury to the fine lines of the design, the layer of nickel has to be produced by galvanoplasty, and the deposit of nickel strengthened in the copper bath.

But upon black-leaded gutta-percha or wax moulds a nickel deposit can only be obtained in fresh baths. The deposit, however, is faultless only in rare cases, it generally showing holes in the depressions. Hence the object has to be attained in a round-about way, the mode of procedure being as follows: An impression of the original is taken in gutta-percha or wax, and from this impression a positive cliché in copper is made. The latter is then silvered, the silvering iodized as previously described, and a negative in copper is then prepared from this positive. The negative is again silvered, iodized, and then brought into a nickel bath, where it receives a deposit of the thickness of stout writing paper. It is then rinsed in water, and the deposit immediately strengthened in the acid copper bath. For the rest, it is treated like ordinary copper deposits. Nickel electrotypes thus made are almost indestructible.

*Galvanoplasty in silver and gold.*—The preparation of reproductions in silver and gold also presents many difficulties. While copper is separable in a compact state from its sulphate solution, silver and gold have to be reduced from their double salt solutions—potassium silver cyanide and potassium gold cyanide. However, these alkaline solutions attack moulds of fatty substances, such as wax and stearine, consequently also,



plaster-of-Paris moulds impregnated with these substances, as well as gutta-percha and gelatine. Hence, only metallic moulds can be advantageously used, except the end is to be attained in a round-about way; that is, by first coating the mould with a thin film of copper, strengthening this in the silver or gold bath, and finally dissolving the film of copper with dilute nitric acid.

The double salt solutions mentioned above require a well-conducting surface such as cannot be readily prepared by black-leading, a further reason why metallic moulds are to be preferred. The simplest way for the galvanoplastic reproduction in gold or silver of surfaces not in high relief or undercut, is to cover the object with lead, silver, or gold foil, and pressing softened gutta-percha upon it; the foil yields to the pressure without tearing, and adheres to the gutta-percha so firmly that it can be readily separated together with it. Galvanoplastic reproductions in the noble metals are so seldom made in practice that it is not necessary to give further details. The composition of the baths generally used is as follows:

*Bath for galvanoplasty in silver.*—Fine silver (in the form of silver cyanide or silver chloride)  $1\frac{3}{4}$  ozs., 98 per cent. potassium cyanide  $5\frac{1}{4}$  ozs., water 1 quart.

*Bath for galvanoplasty in gold.*—Fine gold (in the form of neutral chloride of gold) 1 oz., potassium cyanide  $3\frac{1}{2}$  ozs., water 1 quart.

## CHAPTER XV.

### COLORING, PATINIZING, OXIDIZING, ETC., OF METALS.—

#### LACQUERING.

Though, strictly speaking, these operations do not form a part of a work on the electro-deposition of metals, they require to be mentioned, since the operator is frequently forced to make use of one or the other method in order to furnish basis-metals or electro-deposits in certain shades of colors ordered.

By *patina* is understood the beautiful green color antique statues and other art-works of bronze acquire by long exposure to the action of the oxygen, carbonic acid, and moisture of the air, whereby a thin layer of copper carbonate is formed upon them. It has been sought to accelerate by chemical means the formation of the patina thus slowly produced by the influence of time, and the term *patinizing* has been applied to this artificial production of colors. Without drawing a strict line as to which processes have to be considered as coloring, and which as patinizing, the most approved methods for changing the color of the metals or of the deposits will be given.

1. *Coloring of copper*.—All shades from the pale-red of copper to a dark chestnut-brown can be obtained by superficial oxidation of the copper. For small objects it suffices to heat them uniformly over an alcohol flame. With larger objects a more uniform result is obtained by heating them in oxidizing fluids or brushing them over with an oxidizing paste, the best results being obtained with a paste prepared, according to the darker or lighter shades desired, from 2 parts of ferric oxide and 1 part of black-lead, or 1 part each of ferric oxide and

black-lead, with alcohol or water. Apply the paste as uniformly as possible with a brush, and place the object in a warm place (oven or drying chamber). The darker the color is to be the higher the temperature must be, and the longer it must act upon the object. When sufficiently heated the dry powder is removed by brushing with a soft brush, and the manipulation repeated if the object does not show a sufficiently dark tone. Finally the object is rubbed with a soft linen rag moistened with alcohol, or brushed with a soft brush and a few drops of alcohol until completely dry, and then with a brush previously rubbed upon pure wax. The more or less dark shade produced in this manner is very warm, and resists the action of the air.

*Brown color upon copper* is obtained by applying to the thoroughly cleansed surface of the object a paste of verdigris 3 parts, ferric oxide 3, sal ammoniac 1, and sufficient vinegar, and heating until the applied mixture turns black. The object is then washed and dried. By the addition of some blue vitriol the color may be darkened to chestnut-brown.

In England a *brown layer of cuprous oxide* upon copper articles is produced as follows: After polishing the articles with pumice powder apply with a brush a paste of 4 parts of verdigris, 4 parts of colcothar (ferric oxide), 1 part of finely rasped horn shavings and a small quantity of vinegar. Dry, heat over a coal fire, wash, and smooth with the polishing stone.

A *brown color* is also obtained by brushing to dryness with a hot solution of 1 part of potassium nitrate, 1 of common salt, 2 of ammonium chloride, and 1 of liquid ammonia in 95 of vinegar. A warmer tone is, however, produced by the method introduced in the Paris Mint, which is as follows: Powder and mix intimately equal parts of verdigris and sal ammoniac. Take a heaping tablespoonful of this mixture and boil it with water in a copper kettle for about twenty minutes and then pour off the clear fluid. To give copper objects a bronze-like color with this fluid, pour part of it into a copper pan; place the objects separately in it upon pieces of wood or glass, so

that they do not touch each other, or come in contact with the copper pan, and then boil them in the liquid for a quarter of an hour. Then take the objects from the solution, rub them dry with a linen cloth, and brush them with a waxed brush.

A *red-brown color* on copper is produced in China by the application of a paste of verdigris 2 parts, cinnabar 2, sal ammoniac 5, and alum 5, with sufficient vinegar, heating over a coal fire, washing, and repeating the process.

According to Manduit, copper and coppered articles may be bronzed by brushing with a mixture of castor oil 20 parts, alcohol 80, soft soap 40, and water 40. This mixture produces tones from bronze Barbédienne to antique green patina, according to the duration of the action. After 24 hours the article treated shows a beautiful bronze, but when the mixture is allowed to act for a greater length of time the tone is changed and several different shades of great beauty are obtained. After rinsing, dry in hot saw-dust, and lacquer with colorless spirit lacquer.

*Copper is colored blue-black* by dipping the object in a hot solution of  $11\frac{1}{4}$  drachms of liver of sulphur in 1 quart of water, moving it constantly. *Blue-gray* shades are obtained with more dilute solutions. It is difficult to give definite directions as to the length of time the solution should be allowed to act, since this depends on its temperature and concentration. With some experience the correct treatment, however, will soon be learned.

The so-called *cuivre fumé* is produced by coloring the copper or coppered objects blue-black with solution of liver of sulphur, then rinsing, and finally scratch-brushing them, whereby the shade becomes somewhat lighter. From raised portions which are not to be dark, but are to show the color of copper, the coloration is removed by polishing upon a felt wheel or bob.

*Black color* upon copper is produced by a heated pickle of 2 parts of arsenious acid, 4 of concentrated muriatic acid, 1 of sulphuric acid of 66° Bé., and 24 of water.

*Matt-black on copper.*—Brush the object over with a solution



of 1 part of platinum chloride in 5 of water, or dip it in the solution. A similar result is obtained by dipping the copper object in a solution of nitrate of copper or of manganese, and drying over a coal fire. These manipulations are to be repeated until the formation of a uniform matt-black.

A solution recommended for obtaining a *deep black color* on copper and its alloys is composed as follows: Copper nitrate 100 parts, water 100 parts. The copper nitrate is dissolved in the water, and the article, if large, is painted with it; if small, it may be immersed in the solution. It is then heated over a clear coal fire and lightly rubbed. The article is next placed in, or painted, with a solution of the following composition: Potassium sulphide 10 parts, water 100, hydrochloric acid 5.

More uniform results, however, are obtained by using a solution about three times more dilute than the above, *viz.*: Copper nitrate 100 parts, water 300. Small work can be much more conveniently treated by immersion in the solution, and after draining off, or shaking off, the excess of the solution, heating the work on a hot plate until the copper salt is decomposed into the black copper oxide. It would be difficult to heat large articles on a hot plate, but a closed muffle furnace should give better results than an open coal fire. In any case the heating process should not be continued longer than necessary to produce the change mentioned above.

*Imitation of genuine patina.*—Repeatedly brush the objects with solution of sal ammoniac in vinegar. The action of the solution is accelerated by the addition of verdigris. A solution of 9 drachms of sal ammoniac and  $2\frac{1}{4}$  drachms of potassium binoxalate in 1 quart of vinegar acts still better. When the first coating is dry, wash the object, and repeat the manipulations, drying and washing after each application, until a *green patina* is formed. It is best to bring the articles after being brushed over with the solution into a hermetically closed box, upon the bottom of which a few shallow dishes containing very dilute sulphuric or acetic acid and a few pieces of marble are placed. Carbonic acid being thereby evolved, and the air

in the box being kept sufficiently moist by the evaporation of water, the conditions required for the formation of genuine patina are thus filled. If the patina is to show a more *bluish* tone, brush the objects with a solution of  $4\frac{1}{4}$  ozs. of ammonium carbonate and  $1\frac{1}{2}$  ozs. of sal ammoniac in 1 quart of water, to which a small quantity of gum tragacanth may be added.

To produce a *steel-gray color upon copper* immerse the clean and pickled objects in a heated solution of chloride of antimony in hydrochloric acid. By using a strong electric current the objects may also be coated with a steel-gray deposit of arsenic in a heated arsenic bath.

For coloring copper *dark steel-gray*, a pickle consisting of 1 quart of hydrochloric acid, 0.125 quart of nitric acid,  $1\frac{1}{2}$  ozs. of arsenious acid, and a like quantity of iron filings is recommended.

*Various colors upon massive copper.*—First draw the object through a pickle composed of sulphuric acid 60 parts, hydrochloric acid 24.5, and lampblack 15.5; or of nitric acid 100 parts, hydrochloric acid  $1\frac{1}{2}$ , and lampblack  $\frac{1}{4}$ . Then dissolve in a quart of water  $4\frac{1}{2}$  ozs. of sodium hyposulphite, and in another quart of water  $14\frac{1}{4}$  drachms of blue vitriol,  $5\frac{1}{2}$  drachms of crystallized verdigris, and  $7\frac{3}{4}$  grains of sodium arsenate. Mix equal volumes of the two solutions, but no more than is actually necessary for the work in hand, and heat to between  $167^{\circ}$  and  $176^{\circ}$  F. By dipping articles of copper, brass or nickel in the hot solution they become immediately colored with the colors mentioned below, one color passing within a few seconds into the other, and for this reason the effect must be constantly controlled by frequently taking the objects from the bath. The colors successively formed are as follows:

*Upon copper :*

Orange,  
Terra-cotta,  
Red (pale),  
Blood-red,  
Iridescent.

*Upon brass :*

Golden-yellow,  
Lemon color,  
Orange,  
Terra-cotta,  
Olive-green.

*Upon nickel :*

Yellow,  
Blue,  
Iridescent.

Some of these colors not being very durable, have to be protected by a coat of lacquer or paraffine. It is further necessary to diligently move the objects, so that all portions acquire the same color. The bath decomposes rapidly, and hence only sufficient for 2 or 3 hours' use should be mixed at one time.

2. *Coloring of brass and bronzes.*—Most of the directions given for coloring copper are also available for brass and bronzes, especially those for the production of the *green patina*, and the oxidized tones by a mixture of ferric oxide and black-lead.

Many colorations on brass, however, are effected only with difficulty, and are partially or entirely unsuccessful, as, for instance, coloring black with liver of sulphur. As a pickle for the production of a

*Lustrous black on brass*, the following solution may be used: Dissolve freshly precipitated carbonate of copper, while still moist, in strong liquid ammonia, using sufficient of the copper salt so that a small excess remains undissolved, or, in other words, that the ammonia is saturated with copper. The carbonate of copper is prepared by mixing hot solutions of equal parts of blue vitriol and of soda, filtering off, and washing the precipitate.

Dilute the solution of the copper salt in ammonia with one-fourth its volume of water, add 31 to 46 grains of graphite and heat to between  $95^{\circ}$  and  $104^{\circ}$  F.

According to experiments in the laboratory of the Physikalisch-Technischen Reichsanstalt, the following proportions have proved very effective: Copper carbonate  $3\frac{1}{2}$  ozs., spirits of sal ammoniac  $26\frac{1}{2}$  ozs., and an addition of  $5\frac{1}{4}$  ozs. of water. Place the clean and pickled articles in this pickle until they show a full black tone, then rinse in water, immerse in hot water, and dry in sawdust. The solution soon spoils, and hence no more than required for immediate use should be prepared.

For *black pickling* in the hot way, a solution of 21 ozs. of copper nitrate in 7 ozs. of water mixed with a solution of  $3\frac{3}{4}$  grains of silver nitrate in  $\frac{1}{3}$  oz. of water, is recommended.

Another method of coloring brass black has been given under "Deposition of Arsenic."

Urquhart states that clean brass and copper may be covered with a firmly adherent black coating by placing them very near to the flames of burning straw. The coating will not rub off, and may be polished with a soft cloth.

*Steel-gray on brass* is obtained by the use of a mixture of 1 lb. of strong hydrochloric acid with 1 pint of water, to which are added  $5\frac{1}{4}$  ozs. of iron filings and a like quantity of pulverized antimony sulphide.

Hydrochloric acid compounded with arsenious acid is also recommended for this purpose. The mixture is brought into a lead vessel, and the objects dipped in it should come in contact with the lead of the vessel, or be wrapped around with a strip of lead.

A *gray color with a bluish tint* upon brass is produced with solution of antimonious chloride (butter of antimony), while a pure *steel-gray* color is obtained with a hot solution of arsenious chloride with a little water.

A *pale gold color* on brass is obtained in the following bath: Dissolve in 90 parts by weight of water, 3.6 parts by weight of caustic soda and the same quantity of milk sugar. Boil the solution  $\frac{1}{4}$  hour. Then add a solution of blue vitriol 3.6 parts by weight in 10 of hot water, and use the bath at a temperature of  $176^{\circ}$  F.

*Straw color, to brown, through golden yellow, and tombac color on brass* may be obtained with solution of carbonate of copper in caustic soda lye. Dissolve 5.25 ozs. of caustic soda in 1 quart of water, and add  $1\frac{3}{4}$  ozs. of carbonate of copper. By using the solution cold, a *dark golden-yellow* is first formed, which finally passes through *pale brown* into *dark brown* with a green lustre. Coloration is more rapidly effected by using the solution hot.

A *color resembling gold on brass* is, according to Dr. Kayser, obtained as follows: Dissolve  $8\frac{1}{2}$  drachms of sodium hyposulphite in 17 drachms of water, and add 5.64 drachms of solution of



antimonious chloride (butter of antimony). Heat the mixture to boiling for some time, then filter off the red precipitate formed, and after washing it several times upon the filter with vinegar, suspend it in 2 or 3 quarts of hot water; then heat and add concentrated soda lye until solution is complete. In this hot solution dip the clean and pickled brass objects, removing them frequently to see whether they have acquired the desired coloration. By remaining too long in the bath, the articles become gray.

*Brown color, called bronze Barbédienne, on brass.*—This beautiful color may be produced as follows: Dissolve by vigorous shaking in a bottle, freshly prepared arsenious sulphide in spirit of sal ammoniac, and compound the solution with antimonious sulphide (butter of antimony) until a slight permanent turbidity shows itself, and the fluid has acquired a deep yellow color. Heat the solution to 95° F., and suspend the brass objects in it. They become at first golden-yellow and then brown, but as they come from the bath with a dark dirty tone, they have to be several times scratch-brushed to bring out the color. If, after using it several times, the solution fails to work satisfactorily, add some antimonious sulphide. The solution decomposes rapidly, and should be prepared fresh every time it is to be used.

By this method only massive brass objects can be colored brown. To *brassed zinc* and *iron* the solution imparts brown black tones, which, however, are also quite beautiful.

Upon massive brass, as well as upon brassed zinc and iron objects, bronze Barbédienne may be produced as follows: Mix 3 parts of red sulphide of antimony (*stibium sulfuratum aurantianum*) with 1 part of finely pulverized bloodstone, and triturate the mixture with ammonium sulphide to a not too thickly-fluid pigment. Apply this pigment to the objects with a brush, and, after allowing to dry in a drying chamber, remove the powder by brushing with a soft brush.

In Paris, *bronze articles* are colored *dead-yellow* or *clay-yellow* to *dark brown* by first brushing the pickled and thoroughly rinsed objects with dilute ammonium sulphide, and, after dry-

ing, removing the coating of separated sulphur by brushing. Dilute solution of sulphide of arsenic in ammonia is then applied, the result being a color resembling mosaic gold. The more frequently the arsenic solution is applied, the browner the color becomes. By substituting for the arsenic solution one of sulphide of antimony in ammonia or ammonium sulphide, colorations of a more reddish tone are obtained.

*Smoke-bronze.*—Bronzing with smoke is sometimes resorted to in order to give the metal an ancient appearance. This is effected by exposing the work to the smoke of a fire for some days, when it receives a firm coating of a dark color. The articles are generally suspended over the smoky fire of a furnace by means of brass wire. When the furnace is sufficiently heated the smoke is maintained by burning hay and other substances which produce copious smoke with the coal. When the right tint is attained the articles are removed from the furnace and allowed to cool without touching them with the hands. The hotter the articles have been made the darker will be the color. If the articles which have been smoked have been previously coated with a green bronze, then it is well to finish with a waxed brush.

A *dark red brown* color upon brass is produced by suspending the articles, previously thoroughly freed from grease, in a solution of equal parts of potassium lead oxide and red prussiate of potash heated to  $122^{\circ}$  F. The articles are allowed to remain in the solution until they have acquired a sufficiently dark color.

For coloring *brass articles en masse brown* by boiling, the following solution is recommended: Water 1 quart, potassium chromate  $1\frac{1}{2}$  ozs., nickel sulphate  $1\frac{1}{2}$  ozs., potassium permanganate 77 grammes.

Solution of blue vitriol and potassium permanganate serves the same purpose. However, after boiling, the articles must not be scratch-brushed, but after drying rubbed with vaseline.

*Violet- and corn-flower blue upon brass* may be produced as follows: Dissolve in 1 quart of water  $4\frac{1}{2}$  ozs. of sodium hypo-

sulphite, and in another quart of water 1 oz.  $3\frac{3}{4}$  drachms of crystallized sugar of lead, and mix the solutions. Heat the mixture to  $176^{\circ}$  F., and then immerse the cleansed and pickled articles, moving them constantly. First a gold-yellow coloration appears, which, however, soon passes into violet and blue, and if the bath be allowed to act further, into green. The action is based upon the fact that in an excess of hyposulphite of soda, solution of hyposulphite of lead is formed, which decomposes slowly and separates sulphide of lead, which precipitates upon the brass objects and, according to the thickness of the deposit, produces the various lustrous colors.

Upon the same action is based the spurious gilding of small silvered brass and tombac articles. Though this process has been known for many years, Joseph Dittrich obtained a German patent for it. He uses for  $6\frac{1}{2}$  lbs. of water,  $10\frac{1}{2}$  ozs. of sodium hyposulphite, and  $3\frac{1}{2}$  ozs. of lead acetate (sugar of lead).

Similar lustrous colors are obtained by dissolving 2.11 ozs. of pulverized tartar in 1 quart of water, and 1 oz. of chloride of tin in  $\frac{1}{2}$  pint of water, mixing the solution, heating, and pouring the clear mixture into a solution of 6.34 ozs. of sodium hyposulphite in 1 pint of water. Heat this mixture to  $176^{\circ}$  F., and immerse the pickled brass objects.

*Ebermayer's experiments in coloring brass.*—Below the results of Ebermayer's experiments are given. In testing the directions, the same results as those claimed by Ebermayer were not always obtained; and variations are given in parentheses.

I. Blue vitriol 8 parts by weight, crystallized sal ammoniac 2, water 100, give by boiling a *greenish* color. (The color is *olive-green*, and useful for many purposes. The coloration, however, succeeds only upon massive brass, but not upon brassed zinc.)

II. Potassium chlorate 10 parts by weight, blue vitriol 10, water 1000, give by boiling a *brown-orange* to *cinnamon-brown* color. (Only a *yellow-orange* color could be obtained.)

III. By dissolving 8 parts by weight of blue vitriol in 1000 of water, and adding 100 of caustic soda until a precipitate is

formed, and boiling the objects in the solution a *gray-brown*, color is obtained, which can be made darker by the addition of colcothar. (Stains are readily formed. Brassed zinc acquires a pleasant *pale-brown*.)

IV. With 50 parts by weight of caustic soda, 50 of sulphide of antimony, and 500 of water, a pale *fig-brown* color is produced. (Fig-brown could not be obtained, the shade being rather *dark olive-green*.)

V. By boiling 400 parts by weight of water, 25 of sulphide of antimony and 60 of calcined soda, and filtering the hot solution, *mineral kermes* is precipitated. By taking of this 5 parts by weight and heating with 5 of tartar, 400 of water, and 10 of sodium hyposulphite, a beautiful *steel-gray* is obtained. (The result is tolerably sure and good.)

VI. Water 400 parts by weight, potassium chlorate 20, nickel sulphide 10, give after boiling for some time a *brown* color, which, however, is not formed if the sheet has been pickled. (The brown color obtained is not very pronounced.)

VII. Water 250 parts by weight, potassium chlorate 5, carbonate of nickel 2, and sulphate of ammonium and nickel 5, give after boiling for some time a *brown-yellow color*, playing into a magnificent red. (The results obtained were only indifferent.)

VIII. Water 250 parts by weight, potassium chlorate 5, and sulphate of nickel and ammonium 10, give a beautiful *dark brown*. (Upon massive brass a good dark-brown is obtained. The formula, however, is not available for brassed zinc.)

3. *Coloring zinc*.—The results obtained by coloring zinc directly according to existing directions cannot be relied on, and it is, therefore, recommended to first copper the zinc and then color the coppering. Experiments in coloring zinc *black* with alcoholic solution of chloride of antimony according to Dullas's process gave no useful results. Puscher's method is better. According to it the objects are dipped in a boiling solution of 5.64 ozs. of pure green vitriol and 3.17 ozs. of sal ammoniac in 2½ quarts of water. The loose black precipitate



deposited upon the objects is removed by brushing, the object again dipped in the hot solution, and then held over a coal fire until the sal ammoniac evaporates. By repeating the operation three or four times a firmly-adhering black coating is formed. To color zinc black with nitrate of manganese, as proposed by Neumann, is a tedious operation, it requiring to be repeated seven or eight times. It is done by dipping the object in a solution of nitrate of manganese and heating over a coal fire, the manipulations being repeated until a uniform dead-black is obtained.

*Gray, yellow, brown to black colors upon zinc* are obtained by bringing the articles into a bath which contains 6 to 8 quarts of water,  $3\frac{1}{2}$  ozs. of nickel ammonium sulphate,  $3\frac{1}{2}$  ozs. of blue vitriol and  $3\frac{1}{2}$  ozs. of potassium chlorate. The bath is to be heated to  $140^{\circ}$  F. By increasing the content of blue vitriol a dark color is obtained, and a lighter one with the use of a larger proportion of nickel salt. The correct proportions for the determined shades will soon be learned by practice. When colored, the articles are thoroughly rinsed, dried, without rubbing, in warm sawdust, and finally rubbed with a flannel rag moistened with linseed oil, whereby they acquire deep lustre, and the coating becomes more durable.

By suspending zinc in a nickel bath slightly acidulated with sulphuric acid, a firmly adhering *blue-black* coating is, after some time, formed without the use of a current. This coating is useful for many purposes. A similar result is obtained by immersing the zinc objects in a solution of 2.11 ozs. of the double sulphate of nickel and ammonium and a like quantity of sal ammoniac in 1 quart of water. The articles become first *dark yellow*, then, successively, *brown*, *purple-violet*, and *indigo blue*, and stand slight scratch-brushing and polishing.

A *gray coating on zinc* is obtained by a deposit of arsenic in a heated bath composed of 2.82 ozs. of arsenious acid, 8.46 drachms of sodium pyrophosphate and  $1\frac{3}{4}$  drachms of 98 per cent. potassium cyanide and 1 quart of water. A strong current should be used so that a vigorous evolution of hydrogen

is perceptible. Platinum sheets or carbon plates are used as anodes.

A sort of *bronzing* on zinc is obtained by rubbing it with a paste of pipe-clay to which has been added a solution of 1 part by weight of crystallized verdigris, 1 of tartar, and 2 of crystallized soda.

Kletzinski states that a solution of molybdic acid, or ammonium molybdate, in nitric acid, made very dilute, furnishes a good liquid for producing a brown patina on cast zinc. The object assumes iridescent colors on immersion, which he considers to be due to molybdenum oxide. The following proportions were tried, with the results given below: Ammonium molybdate 1.550 grains, ammonia 2.325 grains, water 1 pint.

Zinc acquired a beautiful iridescent appearance after a few moments' immersion in the solution. On continuing the process, the iridescent colors were succeeded by a light yellowish-brown color, and this, on warming the solution, was followed by a slaty-black, which was more opaque than any of the preceding colors.

Brass and tin are unaffected when immersed alone, but tin when placed in contact with zinc assumes a beautiful dark violet color, which is firmly adherent to the metal. Iron in contact with tin is simply stained.

*Red-brown shades on zinc.*—Rub with solution of chloride of copper in liquid ammonia.

*Yellow brown shades on zinc.*—Rub with solution of chloride of copper in vinegar.

4. *Coloring of iron.*—The browning of gun-barrels is effected by the application of a mixture of equal parts of butter of antimony and olive oil. Allow the mixture to act for 12 to 14 hours, then remove the excess with a woollen rag and repeat the application. When the second application has acted for 12 to 24 hours, the iron or steel will be coated with a bronze-colored layer of ferric oxide with antimony, which resists the action of the air, and may be made lustrous by brushing with a waxed brush.

A patina which protects metals — iron, zinc, tin, etc.— from rust, is, according to Haswell, obtained as follows: The article, previously freed from grease and pickled, is suspended as negative electrode in a solution of  $15\frac{1}{2}$  grains of ammonium molybdate and  $\frac{1}{3}$  oz. of ammonium nitrate in 1 quart of water. A weak current should be used — 0.2 to 0.3 ampère per  $15\frac{1}{2}$  square inches.

To protect gun barrels and other articles of iron and steel from rust, they are, according to Haswell, suspended as anodes in a bath consisting of a solution of lead nitrate and sodium nitrate, into which manganous oxide has been stirred.

A *lustrous black* on iron is obtained by the application of solution of sulphur in spirits of turpentine prepared by boiling upon the water bath. After the evaporation of the spirits of turpentine a thin layer of sulphur remains upon the iron, which on heating the article immediately combines with the metal.

A *lustrous black* is also obtained by freeing the iron articles from grease, pickling, and after drying, coating with sulphur balsam,\* and burning in at a dark-red heat. If pickling is omitted, coating with sulphur balsam and burning-in must be twice or three times repeated.

The same effect is produced by applying a mixture of three parts flower of sulphur, and one part graphite with turpentine and heating in the muffle.

According to Meritens a bright black color can be obtained on iron by making it the anode in distilled water, kept at  $158^{\circ}$  F., and using an iron plate as a cathode. The method was tested as follows: A piece of bright sheet pen-steel was placed in distilled water and made the anode by connecting with the positive pole of a plating dynamo, and a similar sheet was connected with the negative pole to form the cathode. An electromotive force of 8 volts was employed. After some time a dark stain was produced, but it lacked uniformity. The experiment was repeated with larger plates, when a good blue-black

\* Sulphur dissolved in linseed oil.

color was obtained on the anode in half an hour. On drying out in sawdust the color appeared less dense, and inclined to a dark straw tint. The back of the plate was also colored, but not regularly. The face of the cathode was discolored with a grayish stain on the side opposite to the anode, but on the other side the appearance was almost identical with the back of the anode. The water became of a yellowish color.

Fresh distilled water was then boiled for a long time so as to expel all trace of the oxygen absorbed from the atmosphere, and the experiment repeated as in the former cases. No perceptible change took place after the connection had been made with the dynamo for a quarter of an hour. After the interval of one hour a slight darkening occurred, but the effect was much less than that produced in five minutes in aerated water.

The action of the liquid in coloring the steel is evidently one of oxidation, due to the dissolved oxygen, which becomes more chemically active under the influence of the electric condition, and gradually unites with the iron.

The dead black coating on clock cases of iron and steel is not produced by the galvanic process. For this purpose it is recommended to brush the slightly heated metallic parts with a solution of 70 parts copper nitrate in 30 parts spirits of wine and then heat them. A black coating of copper oxide is formed, which after cooling is rubbed off, and an adhering gray layer remains behind. By repeating the operation pure black tones are obtained.

According to Böttger a durable *blue* on iron and steel may be obtained by dipping the article in a  $\frac{1}{2}$  per cent. solution of red prussiate of potash mixed with an equal volume of a  $\frac{1}{2}$  per cent. ferric chloride solution.

*A brown-black coating with bronze lustre* on iron is obtained by heating the bright iron objects and brushing them over with concentrated solution of potassium bichromate. When dry, heat them over a charcoal fire, and wash until the water running off shows no longer a yellow color. Repeat the operation twice or three times. A similar coating is obtained by



heating the iron objects with a solution of 10 parts by weight of green vitriol and 1 part of sal ammoniac in water.

*To give iron a silvery appearance with high lustre.*—Scour the polished and pickled iron objects with a solution prepared as follows: Heat moderately  $1\frac{1}{2}$  ozs. of chloride of antimony, 0.35 oz. of pulverized arsenious acid, 2.82 ozs. of elutriated bloodstone with 1 quart of 90 per cent. alcohol upon a water bath for half an hour. Partial solution takes place. Dip into this fluid a tuft of cotton and go over the iron portions, using slight pressure. A thin film of arsenic and antimony is thereby deposited, which is the more lustrous the more carefully the iron has previously been polished.

5. *Coloring of tin.*—A *bronze-like patina* on tin may be obtained by brushing the object with a solution of  $1\frac{3}{4}$  ozs. of blue vitriol and a like quantity of green vitriol in 1 quart of water, and moistening, when dry, with a solution of  $3\frac{1}{2}$  ozs. of verdigris in  $10\frac{1}{2}$  ozs. of vinegar. When dry, polish the object with a soft waxed brush and some ferric oxide. The coating thus obtained being not very durable, must be protected by a coating of lacquer.

*Durable and very warm sepia-brown tone upon tin and its alloys.*—Brush the object over with a solution of 1 part of platinum chloride in 10 of water, allow the coating to dry, then rinse in water, and, after again drying, brush with a soft brush until the desired brown lustre appears.

A *dark* coloration is also obtained with ferric chloride solution.

6. *Coloring of silver*—See "Deposition of Silver," p. 331.

### *Lacquering.*

In the electro-plating industry recourse is frequently had to lacquering in order to make the deposits more resistant against atmospheric influences, or to protect artificially prepared colors, patinas, etc. Thin, colorless shellac solution, which does not affect the color of the deposit or of the patinizing, is, as a rule, employed, while in some cases colored lacquers are used to

heighten the tone of the deposit, as, for instance, gold lacquer for brass.

The lacquer is applied by means of a fine flat fitch-brush, the object having previously been heated hand-warm. After lacquering, the object is dried in an oven at a temperature of between 140° and 158° F., whereby small irregularities are adjusted, and the layer of lacquer becomes transparent, clear, and lustrous.

Electro-plated articles which are to be lacquered must be thoroughly rinsed and dried to remove adhering plating solution from the pores, otherwise ugly stains will form under the coat of lacquer.

If it becomes necessary to thin a spirit lacquer, only absolute alcohol, *i. e.*, alcohol free from water, should be used for the purpose, since alcohol containing water renders the coat of lacquer muddy and dull.

A few words may here be said in regard to the processes by which those beautiful effects are obtained which imitate so completely the appearance, freshness and rich tones of real gilding. In general, gold varnish is applied only upon copper and its more or less yellow alloys.

Gold varnishers operate as follows: After the objects have been perfectly cleansed, scratch-brushed, and burnished, if necessary, they are completely dried in hot sawdust and wiped clean with a fine cloth. A light coat of varnish is then applied with a fitch-pencil, and all excess of varnish removed or leveled with another flat brush of badger-hair or bristles. The two brushes are kept together in the same hand, the varnish brush between the thumb and first two fingers, while the flat one (without a handle) is held between the other fingers and the palm of the hand. In this manner there is no interval in the use of the two brushes. The varnish is kept in a jelly-pot or other similar vessels, across the top of which a string has been stretched. This string is intended for removing by wiping the excess of varnish taken up by the brush or pencil. The varnish which covers the burnished parts of the object may be re-

moved with a clean rag moistened with alcohol and wrapped round the finger. Another dry cloth finishes the drying. Sometimes the burnished parts are also varnished, but the operation is very difficult when their surface is considerable. Round-ware, polished or burnished, may be varnished in the lathe.

After the varnish has been applied as uniformly as possible, the objects are put in a drying stove heated to between  $140^{\circ}$  and  $175^{\circ}$  F. The alcohol or essential oils of the varnish are rapidly volatilized, while the resins or gums melt and cover the objects with a glassy lustre. The heat must be sufficient to melt these gums, but low enough to avoid burning them. When the operation has been well performed, the pieces present a beautiful and uniform golden appearance, with no disfiguring red patches, which latter indicate an unequal thickness of varnish.

Varnishers have always at their disposal four varnishes of different shades—*red gold, orange-yellow gold, green gold, and colorless varnish for mixture*. This last is employed for diluting the first three and diminishing the depth of their colors. Each of these various varnishes gives to copper the gold color peculiar to it, and, when mixed, intermediary shades. It often happens that the various parts of a large piece are different in composition and color, and the varnisher is obliged to impart the same shade of gold all over by skilful combinations of varnishes. He thus succeeds in giving the same gold color to half-red copper and to alloys of yellow and green brass.

But a small quantity of varnish is poured into the varnish pot at one time, to prevent it from thickening by evaporation, and after the operation the residue is poured back into the flask from which it was taken and kept well stoppered. The brushes and pencils must be often washed in alcohol, which may afterwards be used for diluting thick varnishes.

These varnishes are made by dissolving various resinous substances, like sandarac, benzoin, dragon's-blood, elemi, gamboge, etc., and tinctorial matters, such as saffron, annotto, alkanet, etc., in a mixture of alcohol with essence of lavender or of

spikenard. All qualities of varnish are to be found, but the more expensive are often the more economical.

To remove the varnish from an imperfectly varnished object or from an old one, it is immersed in alcohol or concentrated sulphuric acid, or, better still, in a boiling solution of caustic lye. The varnishing is then begun anew.

*Cellulose lacquers and varnishes.*—Under the name of *zapon* a dip-lacquer has been introduced in commerce. It represents a clear, almost colorless fluid of the consistency of collodion, and smells something like fruit ether. According to G. Buchner, it consists essentially of a solution of cellulose in a mixture of amyl acetate and acetone. Of the last two bodies, the “thinning fluid,” which accompanies the preparation, also consists. This lacquer can be highly recommended, its superiority being due to the favorable properties of the cellulose. The transparent, colorless coat obtained with *zapon* can be bent with the metallic sheet to which it has been applied without cracking. It is so hard that it can scarcely be scratched with the finger-nail, shows no trace of stickiness, and it is perfectly homogeneous even on the edges. This favorable behavior is very likely due to the slow evaporation of the solvent, and the fact that the lacquer quickly forms a thickish, tenacious layer, which, though moved with difficulty, is not entirely immobile. Another advantage of *zapon*—especially as regards metallic objects—is that the coating, in consequence of its physical constitution, preserves the character of the basis. In accordance with the nature of cellulose, the coating is not sensibly affected by ordinary differences in temperature, and does not become dull and non-transparent, as is the case with resins, in consequence of the loss of molecular coherence. It can be washed with soap and water, and protects metals coated with it from the action of the atmosphere. *Zapon* may also be colored, but, of course, only with coloring substances—mostly aniline colors—which are soluble in the solvent used for the cellulose.

A similar preparation is known as *kristaline*. It is a hard, transparent enamel, which can be applied as a lacquer in al



kinds of metal-work without affecting the most delicate finish. It is applied by dipping, is invisible, and leaves no mark in drying.

Kristaline has now been in use for some ten years, and can be relied upon to protect all metal-work from acids and alkalis, also coal-gas, alcohol, benzine, oil, water, fly-specks, etc. It is especially designed to prevent the highest class of metal-work from tarnishing and to preserve the delicate shades of color produced by electricity and artificial oxidation.

A lacquer similar to zapon or kristaline may be prepared by substituting soluble pyroxylin for cellulose, the process being as follows: Bring collodion-cotton, *i. e.*, soluble pyroxylin, such as is used by photographers, into a box which can be hermetically closed, and place upon the bottom of the box a dish with sulphuric acid. The purpose of this is to dry the collodion-cotton, which requires from 36 to 48 hours. The collodion-cotton is then brought into a large bottle, and three to four times its quantity by weight of very strong alcohol poured over it. In a few days the greater portion of it is dissolved, when the clear solution is poured into another bottle. Add to the clear solution more collodion-cotton, about 25 to 30 per cent. of the weight of the quantity originally used, and the resulting product forms an excellent cellulose lacquer, which rapidly hardens to a perfectly transparent and very glossy coating. For diluting cellulose lacquers it is best to use wood spirit. To color them, dissolve an aniline color in strong spirits of wine, add a corresponding quantity of the solution to the lacquer, and shake vigorously.

For lacquering articles by dipping, they should be as clean as for plating, and so arranged that the lacquer will run off properly. Allow them to drip over the drip tank until the lacquer stops flowing. Dry in a temperature of 100° F., if possible, using a thermometer. Dip lacquers will dry in the air, but baking improves the finish. Use a tin-lined wooden tank for holding the lacquer, or a chemically enameled iron tank or a glass tank. When not in use cover with a wooden or sheet galvanized cover.

## CHAPTER XVI.

### HYGIENIC RULES FOR THE WORKSHOP.

In but few other branches of industry has the workman so constantly to deal with powerful poisons, as well as other substances and vapors, which are exceedingly corrosive in their action upon the skin and the mucous membranes, as in electro-plating. However, with ordinary care and sobriety, all influences injurious to health may be readily overcome.

The necessity of frequently renewing the air in the workshop by thorough ventilation has already been referred to in Chapter IV., "Electro-plating establishments in general." Workmen exclusively engaged in pickling objects are advised to neutralize the action of the acid upon the enamel of the teeth and the mucous membranes of the mouth and throat by frequently rinsing the mouth with dilute solution of bicarbonate of soda. Workmen engaged in freeing the objects from grease lose, for want of cleanliness, the skin on the portions of the fingers which come constantly in contact with the lime and caustic lyes. This may be overcome by frequently washing the hands in clean water, and previous to each intermission in the work, the workman should, after washing the hands, dip them in dilute sulphuric acid, dry them, and thoroughly rub them with cosmoline, or a mixture of equal parts of glycerine and water. The use of rubber gloves by workmen engaged in freeing the objects from grease cannot be recommended, they being expensive and subject to rapid destruction. It is better to wrap a linen rag seven or eight times around a sore finger, many workmen using this precaution to protect the skin from the corrosive action of the lime.

It should be a rule for every workman employed in an

electro-plating establishment not to drink from vessels used in electroplating manipulations; for instance, porcelain dishes, beer glasses, etc. One workman may this moment use such a vessel to drink from, and without his knowledge another may employ it the next moment for dipping out potassium cyanide solution, and the first using it again as a drinking vessel may incur sickness or even fatal poisoning. The handling of potassium cyanide and its solutions requires constant care and judgment. Working with sore hands in such solutions should be avoided as much as possible; but if it has to be done, and the workman feels a sharp pain in the sore, wash the latter quickly with clean water and apply a few drops of green vitriol solution. Many individuals are very sensitive to nickel solutions, eruptions which are painful and heal slowly breaking out upon the arms and hands, while others may for years come in contact with nickel baths without being subject to eruptions. In such case prophylaxis is also the safeguard, *i. e.*, to prevent by immediate thorough washing the formation of the eruption if the skin has been brought in contact with the nickel solution, as, for instance, in taking out with the hand an object which has dropped into a nickel bath.

Below will be found some directions for neutralizing, in case of internal poisoning, the effects of the poison either entirely or at least sufficiently to retard its action until professional aid can be summoned.

*Poisoning by hydrocyanic (prussic) acid, potassium cyanide, or cyanides.*—If prussic acid, or the cyanides, be concentrated or have been absorbed in considerable quantity, their action is almost instantly fatal, and there is little hope of saving the victim, although everything possible should be tried. But if these substances have been taken in very dilute condition, they may not prove immediately fatal, and there is some hope that remedial measures may be successfully applied.

In poisoning with these substances, *water as cold as possible* should be run upon the head and spine of the patient, and he should be made to inhale, carefully and moderately, the vapor

of chlorine water, bleaching powder, or Javelle water (hypochlorite of soda).

Should these poisons be introduced into the stomach, there should be administered as soon as possible the hydrate of sesquioxide of iron, or, what is better, dilute solutions of the acetate, citrate, or tartrate of iron. With proper precautions a very dilute solution of sulphate of zinc may be given.

*Poisoning by copper-salts.*—The stomach should be quickly emptied by means of an emetic or, in want of this, the patient should thrust his finger to the back of his throat and induce vomiting by tickling the *uvula*. After vomiting drink milk, white of egg, gum-water, or some mucilaginous decoction.

*Poisoning by lead-salts* requires the same treatment as poisoning by copper-salts. Lemonade of sulphuric acid or an alkaline solution containing carbonic acid, such as Vichy water or bicarbonate of soda, is also very serviceable.

*Poisoning by arsenic.*—The stomach must be quickly emptied by an energetic emetic, when freshly precipitated ferric hydrate and calcined magnesia may be given as an antidote. Calcined magnesia being generally on hand, mix it with 15 or 20 times the quantity of water, and give this mixture 3 to 6 tablespoonfuls every 10 to 15 minutes.

*Poisoning by alkalies.*—Use weak acids, such as vinegar, lemon-juice, etc., and in their absence sulphuric, hydrochloric or nitric acid diluted to the strength of lemonade. After the pain in the stomach has diminished, it will be well to administer a few spoonfuls of olive oil.

*Poisoning by mercury salts.*—Mercury salts, and particularly the chloride (corrosive sublimate), form with the white of egg (albumen) a compound very insoluble and inert. The remedy, albumen, is therefore indicated. Sulphur and sulphuretted water are also serviceable for the purpose.

*Poisoning by sulphuretted hydrogen.*—The patient should be made to inhale the vapor of chlorine from chlorine water, Javelle water, or bleaching-powder. Energetic friction, especially at the extremities of the limbs, should be employed.



Large quantities of warm and emollient drinks should be given, and abundance of fresh air.

*Poisoning by chlorine, sulphurous acid, nitrous and hyponitric gases.*—Admit immediately an *abundance of fresh air*, and administer *light* inspirations of ammonia. Give plenty of hot drinks and excite friction, in order to conserve the warmth and transpiration of the skin. Employ hot foot-baths to remove the blood from the lungs. Afterwards maintain in the mouth of the patient some substance which, melting slowly, will keep the throat moist, such as jujube and marshmallow paste, molasses candy, and licorice paste. Milk is excellent.

## CHAPTER XVII.

### CHEMICAL PRODUCTS AND VARIOUS APPARATUS AND INSTRUMENTS USED IN ELECTRO-PLATING.

#### A. CHEMICAL PRODUCTS.

Below the characteristic properties of the chemical products employed in the workshop will be briefly discussed, and the reactions indicated which allow of their recognition. It frequently happens that the labels become detached from the bottles and boxes, thus rendering the determination of their contents necessary.

##### I. *Acids.*

1. *Sulphuric acid (oil of vitriol).*—Two varieties of this acid are found in commerce, viz., fuming sulphuric acid (disulphuric acid), and ordinary sulphuric acid. The first is a thick oily fluid generally colored yellowish by organic substances, and emits dense white vapors in the air. Its specific gravity is 1.87 to 1.89. The only purpose for which fuming sulphuric acid is used in the electro-plating art is as a mixture with nitric acid, for stripping silvered objects.

Ordinary sulphuric acid has a specific gravity of 1.84. Diluted with water it serves for filling the Bunsen elements and as a pickle for iron; in a concentrated state it is used in the preparation of pickles and as an addition to the galvanoplastic copper bath. The crude commercial acid generally contains arsenic, hence care must be had to procure a pure article. In diluting the acid with water, it should in all cases be added to the water in a very gentle stream and with constant stirring, as otherwise a sudden generation of steam of explosive violence might result, and the dangerous corrosive liquid be scattered in all directions. Concentrated sulphuric acid vigorously attacks

all organic substances, and hence has to be kept in bottles with glass stoppers, and bringing it in contact with the skin should be carefully avoided.

*Recognition.*—One part of the acid mixed with 25 parts of distilled water gives, when compounded with a few drops of barium chloride solution, a white precipitate of barium sulphate.

2. *Nitric acid (aqua fortis, spirit of nitre).*—It is found in trade of various degrees of strength. For our purposes acid of 40° and 30° Bé., is generally used. The acid is usually a more or less deep yellow, and frequently contains chlorine. The vapors emitted by nitric acid are poisonous and of a characteristic odor, by which the concentrated acid is readily distinguished from other acids. It is used for filling the Bunsen elements (carbon in nitric acid), and for pickling in combination with sulphuric acid and chlorine. On coming in contact with the skin it produces yellow stains.

*Recognition.*—By heating the not too dilute acid with copper, brown-red vapors are evolved. For the determination of dilute nitric acid, add a few drops of it to green vitriol solution, when a black-brown coloration will be produced on the point of contact.

3. *Hydrochloric acid (muriatic acid).*—The pure acid is a colorless fluid which emits abundant fumes in contact with the air, and has a pungent odor by which it is readily distinguished from other acids. The specific gravity of the strongest hydrochloric acid is 1.2. The crude acid of commerce has a yellow color, due to iron, and contains arsenic. Dilute hydrochloric acid is used for pickling iron and zinc.

*Recognition.*—On adding to the acid very much diluted with distilled water a few drops of solution of nitrate of silver in distilled water, a heavy white precipitate is formed, which becomes black by exposure to the light.

4. *Hydrocyanic acid (prussic acid).*—This extremely poisonous acid exists in nature only in a state of combination in certain vegetables and fruits, and especially in the kernels of

the latter, as, for instance, in the peach, the berries of the cherry laurel, bitter almonds, the stones of the apricot, of plums, cherries, etc. It may be obtained anhydrous, but, in this state it is useless, and very difficult to preserve from decomposition. Diluted hydrocyanic acid is colorless, with a bitter taste and the characteristic smell of bitter almonds. It is employed in the preparation of gold immersing baths, and for the decomposition of the potassa in old silver baths. The inhalation of the vapors of this acid may have a fatal effect, as also its coming in contact with wounds.

*Recognition.* — By its characteristic smell of bitter almonds. Or mix it with potash lye until blue litmus paper is no longer reddened, then add solution of green vitriol which has been partially oxidized by standing in the air, and acidulate with hydrochloric acid. A precipitate of Berlin blue is formed.

5. *Citric acid.* — Clear colorless crystals of 1.542 specific gravity, which dissolve with great ease in both hot and cold water. It is frequently employed for acidulating nickel baths, and, combined with sodium citrate, in the preparation of platinum baths.

*Recognition.* — Lime-water compounded with aqueous solution of citric acid remains clear in the cold, but on boiling deposits a precipitate of calcium citrate. The precipitate is soluble in ammonium chloride, but on boiling is again precipitated, and is then insoluble in sal ammoniac.

6. *Boric acid (boracic acid).* — This acid is found in commerce in the shape of scales with nacreous lustre and greasy to the touch; when obtained from solutions by evaporation, it forms colorless prisms. Its specific gravity is 1.435; it dissolves with difficulty in cold water (1 part of acid requiring, at 64.4° F., 28 of water), but is more rapidly soluble in boiling water (1 part of acid requiring 3 of water at 212° F.). According to Weston's proposition, boric acid is employed as an addition to nickel baths, etc.

*Recognition.* — By mixing solution of boric acid in water with some hydrochloric acid and dipping turmeric paper in the solu-



tion, the latter acquires a brown color, the color becoming more intense on drying. Alkalies impart to turmeric paper a similar coloration, which, however, disappears on immersing the paper in dilute hydrochloric acid.

7. *Arsenious acid* (*white arsenic, arsenic, ratsbane*).—It generally occurs in the shape of a white powder, and sometimes in vitreous-like lumps, resembling porcelain. For our purposes the white powder is almost exclusively used. It is slightly soluble in cold water, and more readily so in hot water and hydrochloric acid. Notwithstanding its greater specific gravity, (3.7) only a portion of the powder sinks to the bottom on mixing it with water, another portion being retained on the surface by air bubbles adhering to it. It is employed as an addition to brass baths, further, in the preparation of arsenic baths, for blacking copper alloys, and in certain silver whitening baths.

*Recognition.*—When a small quantity of arsenious acid is thrown upon glowing coals an odor resembling that of garlic is perceptible. By mixing solution of arsenious acid, prepared by boiling with water, with a few drops of ammoniacal solution of nitrate of silver, a yellow precipitate of arsenate of silver is obtained. The ammoniacal solution of nitrate of silver is prepared by adding ammonia to solution of nitrate of silver until the precipitate at first formed disappears.

8. *Chromic acid.*—It forms crimson-red needles, and also occurs in commerce in the shape of a red powder. It is readily soluble in water, forming a red fluid which serves for filling batteries.

*Recognition.*—Chromic acid can scarcely be mistaken for any other chemical product employed by the electro-plater. A very much diluted solution of it gives, after neutralization with caustic alkali and adding a few drops of nitrate of silver solution, a crimson-red precipitate of chromate of silver.

9. *Hydrofluoric acid.*—A colorless, corrosive, very mobile liquid of a sharp, pungent odor. The anhydrous acid fumes strongly in the air and attracts moisture with avidity. Hydro-

fluoric acid is used for etching glass and for pickling aluminium dead white. Great care must be observed in working with the acid, since not only the aqueous solution, but also the vapors, have an extremely corrosive effect upon the skin and respiratory organs.

*Recognition.*—By covering a small platinum dish containing hydrofluoric acid with a glass-plate free from grease, the latter in half an hour appears etched.

## II. *Alkalies and Alkaline Earths.*

10. *Potassium hydrate (caustic potash).*—It is found in commerce in various degrees of purity, either in sticks or cakes. It is very deliquescent, and dissolves readily in water and alcohol; by absorbing carbonic acid from the air it rapidly becomes converted into the carbonate, and thus loses its caustic properties. It should, therefore, be kept in well-closed vessels. Substances moistened with solution of caustic potash give rise to a peculiar soapy sensation of the skin when touched. It should never be allowed to enter the mouth, as even dilute solutions almost instantaneously remove the lining of tender skin. Should such an accident happen, the mouth should be at once several times rinsed with water and then with very dilute acetic acid. Pure caustic potash serves as an addition to zinc baths, gold baths, etc. For the purpose of freeing objects from grease the more impure commercial article is used.

11. *Sodium hydrate (caustic soda).*—It also occurs in commerce in various degrees of purity, either in sticks or lumps. It is of a highly caustic character, resembling potassium hydrate (see above) in properties and effects. It is employed for freeing objects from grease.

12. *Ammonium hydrate (ammonia or spirits of hartshorn).*—It is simply water saturated with ammonia gas. By exposure ammonia gas is gradually evolved, so that it must be kept in closely-stoppered bottles, in order to preserve the strength of the solution unimpaired. Four qualities are generally found in commerce, viz., ammonia of 0.910 specific gravity (contain-

ing 24.2 per cent. of ammonia gas); of 0.920 specific gravity (with 21.2 per cent. of ammonia gas); of 0.940 specific gravity (with 15.2 per cent. of ammonia gas); and 0.960 specific gravity (with 9.75 per cent. of ammonia gas). It is employed for neutralizing nickel and cobalt baths when too acid, in the preparation of fulminating gold, and as an addition to some copper and brass baths.

*Recognition.*—By the odor.

13. *Calcium hydrate (burnt or quick lime).*—It forms hard, white to gray pieces, which on moistening with water crumble to a light white powder, evolving thereby much heat. Vienna lime is burnt lime containing magnesia. Lime serves for freeing objects from grease, and for this purpose is made into a thinly-fluid paste with chalk and water with which the objects to be freed from grease are brushed. Vienna lime is much used as a polishing agent.

### III. Sulphur Combinations.

14. *Sulphuretted hydrogen (sulphydric acid, hydrosulphuric acid).*—A very poisonous colorless gas with a fetid smell resembling that of rotten eggs. Ignited in the air, it burns with a blue flame, sulphurous acid and water being formed. At the ordinary temperature water absorbs about three times its own volume of the gas, and then acquires the same properties as the gas itself. Sulphuretted hydrogen serves for the metallizing of moulds as described on p. 455, where the manner of evolving it is also given. It is sometimes employed for the production of "oxidized" silver. Care should be taken not to bring metallic salts, gilt or silvered articles, or pure gold and silver in contact with sulphuretted hydrogen, they being rapidly sulphurized by it.

*Recognition.*—By its penetrating smell; further, by a strip of paper moistened with sugar of lead solution becoming black when brought into a solution of sulphuretted hydrogen or an atmosphere containing it.

15. *Potassium sulphide (liver of sulphur).*—It forms a hard

green-yellow to pale brown mass, with conchoidal fracture. It readily absorbs moisture, whereby it deliquesces and smells of sulphuretted hydrogen. It is employed for coloring copper and silver black.

*Recognition.*—On pouring an acid over liver of sulphur, sulphuretted hydrogen is evolved with effervescence, sulphur being at the same time separated.

16. *Ammonium sulphide (sulphydrate or hydrosulphate of ammonia).*—When freshly prepared it forms a clear and colorless fluid, with an odor of ammonia and sulphuretted hydrogen; by standing it becomes yellow, and, later on, precipitates sulphur. It is used for the same purpose as liver of sulphur.

17. *Carbon disulphide or bisulphide.*—Pure carbon disulphide is a colorless and transparent liquid, which is very dense, and exhibits the property of double refraction. Its smell is characteristic and most disgusting, and may be compared to that of rotten turnips. It burns with a blue flame of sulphurous acid, carbonic acid being at the same time produced. It is used as a solvent for phosphorus and caoutchouc in metallizing moulds according to Parkes' method. This solution should be very carefully handled.

18. *Antimony sulphide.*—a. *Black sulphide of antimony (stibium sulfuratum nigrum)* is found in commerce in heavy, gray and lustreless pieces or as a fine black-gray powder, with slight lustre. It serves for the preparation of antimony baths, and for coloring copper alloys black.

b. *Red sulphide of antimony (stibium sulfuratum aurantiacum)* forms a delicate orange-red powder without taste or odor; it is insoluble in water, but soluble in ammonium sulphide, spirits of hartshorn and alkaline lyes. In connection with ammonium sulphide or ammonia it serves for coloring brass brown.

19. *Arsenic trisulphide or arsenious sulphide (orpiment).*—It is found in commerce in the natural, as well as artificial, state, the former occurring mostly in kidney-shaped masses of a lemon color, and the later in more orange-red masses, or as a



dull yellow powder. Specific gravity 3.46. It is soluble in the alkalis and spirits of sal ammoniac.

20. *Ferric sulphide*.—Hard black masses generally in flat plates, which are only used for the evolution of sulphuretted hydrogen.

#### IV. Chlorine Combinations.

21. *Sodium chloride (common salt, rock salt)*.—The pure salt should form white cubical crystals, of which 100 parts of cold water dissolve 36, hot water dissolving slightly more. The specific gravity of sodium chloride is 2.2. In electroplating sodium chloride is employed as a conducting salt for some gold baths, as a constituent of argentiferous pastes, and for precipitating the silver as chloride from argentiferous solutions.

*Recognition*.—An aqueous solution of sodium chloride on being mixed with a few drops of lunar caustic solution yields a white caseous precipitate, which becomes black by exposure to light, and does not disappear by the addition of nitric acid, but is dissolved by ammonia in excess.

22. *Ammonium chloride (sal ammoniac)*.—A white substance found in commerce in the shape of tough fibrous crystals. It has a sharp saline taste, and is soluble in  $2\frac{3}{4}$  parts of cold, and in a much smaller quantity of hot water. By heat it is sublimed without decomposition. It serves for soldering and tinning, and as a conducting salt for many baths.

*Recognition*.—By sublimation on heating. By adding to a saturated solution of the salt a few drops of solution of platinum chloride, a yellow precipitate of platoso-ammonium chloride is formed.

23. *Antimony trichloride (butter of antimony)*.—A crystalline mass which readily deliquesces in the air. Its solution in hydrochloric acid yields the *liquor stibii chlorati*, also called liquid butter of antimony. It has a yellowish color, and on mixing with water yields an abundant white precipitate, soluble in potash lye. The solution serves for coloring brass steel-gray, and for browning gun-barrels.

24. *Arsenious chloride*.—A thick oily fluid, which evaporates in the air with the emission of white vapors.

25. *Copper chloride*.—Blue-green crystals readily soluble in water. The concentrated solution is green, and the dilute solution blue. On evaporating to dryness, brown-yellow copper chloride is formed. It is employed in copper and brass baths as well as for patinizing,

26. *Tin chloride*.—a. *Stannous chloride or tin salt*. A white crystalline salt readily soluble in water, but its solution on exposure to the air becomes turbid; by adding, however, hydrochloric acid, it again becomes clear. On fusing the crystallized salt loses its water of crystallization, and forms a solid non-transparent mass of a pale yellow color—the fused tin salt. The crystallized, as well as the fused, salt serves for the preparation of brass, bronze and tin baths.

*Recognition*.—By pouring hydrochloric acid over a small quantity of tin salt and adding potassium chromate solution, the solution acquires a green color. By mixing dilute tin salt solution with some chlorine water and adding a few drops of gold chloride solution, purple of Cassius is precipitated; very dilute solutions acquire a purple color.

b. *Stannic chloride* occurs in commerce in colorless crystals, and in the anhydrous state forms a yellowish, strongly fuming caustic liquid known as the “fuming liquor of Libadius.”

27. *Zinc chloride (hydrochlorate or muriate of zinc; butter of zinc)*.—A white crystalline or fused mass which is very soluble and deliquescent. The salt prepared by evaporation generally contains some zinc oxychloride, and hence does not yield an entirely clear solution. It serves for preparing brass and zinc baths, and its solution for nickeling by immersion, soldering, etc.

*Recognition*.—Solution of caustic potash separates a voluminous precipitate of zinc oxhydrate, which redissolves in an excess of the caustic potash solution. By conducting sulphuretted hydrogen into a solution of a zinc salt acidulated with acetic acid, a precipitate of white zinc sulphide is formed.

28. *Zinc chloride and ammonium chloride.*— This salt is a combination of zinc chloride with sal ammoniac, and forms a white very deliquescent powder. Its solution serves for soldering and for zincking by contact.

29. *Nickel chloride.*— It is found in commerce in the shape of deep green crystals and of a pale green powder. The latter contains considerably less water and less free acid than the crystallized article, and is to be preferred for electro-plating purposes. The crystallized salt dissolves readily in water, and the powder somewhat more slowly. Should the solution of the latter deposit a yellow precipitate, consisting of basic nickel chloride, it has to be brought into solution by the addition of a small quantity of hydrochloric acid. Nickel chloride is employed for nickel baths.

*Recognition.*— By mixing the green solution of the salt with some spirits of sal ammoniac, a precipitate is formed, which dissolves in an excess of spirits of sal ammoniac, the solution showing a deep blue color.

30. *Cobalt chloride.*— It forms small rose-colored crystals, which, on heating, yield their water of crystallization, and are converted into a blue mass. The crystals are readily soluble in water, while the anhydrous blue powder dissolves slowly. Cobalt chloride is employed for the preparation of cobalt baths.

*Recognition.*— Caustic potash precipitates from a solution of cobalt chloride a blue basic salt which is gradually converted into a rose-colored hydrate, and, with the access of air, into green-brown cobaltous hydrate. The aqueous solution yields with solution of yellow prussiate of potash a pale gray-green precipitate.

31. *Silver chloride.*— A heavy white powder which by exposure to light becomes gradually blue-gray, then violet and finally black. When precipitated from silver solutions, a caseous precipitate is separated. At 500° F. it fuses without being decomposed, to a yellowish fluid which, on cooling, congeals to a transparent, tenacious, horn-like mass. Silver chloride is

practically insoluble in water, but dissolves with ease in spirits of sal ammoniac and in potassium cyanide solution. It is employed in the preparation of baths for silver-plating, for silvering by boiling, and in the pastes for silvering by friction.

*Recognition.*—By its solubility in ammonia, pulverulent metallic silver being separated from the solution by dipping in it bright ribands of copper.

32. *Gold chloride (terchloride of gold, muriate of gold, auric chloride).*—This salt occurs in commerce as crystallized gold chloride of an orange-yellow color, and as a brown crystalline mass, which is designated as neutral gold chloride, or as gold chloride free from acid, while the crystallized article always contains acid, and, hence, should not be used for gold baths. Gold chloride absorbs atmospheric moisture and becomes resolved into a liquid of a fine gold color. On being moderately heated, yellowish-white aurous chloride is formed, and on being subjected to stronger heat it is decomposed to metallic gold and chlorine gas. By mixing its aqueous solution with ammonia, a yellow-brown powder consisting of *fulminating gold* is formed. In a dry state this powder is highly explosive, and, hence, when precipitating it from gold chloride solution for the preparation of gold baths, it must be used while still moist.

*Recognition.*—By the formation of the precipitate of fulminating gold on mixing the gold chloride solution with ammonia. Further by the precipitation of brown metallic gold powder on mixing the gold chloride solution with green vitriol solution.

33. *Platinic chloride.*—The substance usually known by this name is *hydroplatinic chloride*. It forms red-brown very soluble—and in fact deliquescent—crystals. With ammonium chloride it forms platoso-ammonium chloride (see p. 376). Both combinations are used in the preparation of platinum baths. The solution of platinic chloride also serves for coloring silver, tin, brass and other metals.

*Recognition.*—By the formation of a precipitate of yellow



platoso-ammonium chloride by mixing concentrated platinic chloride solution with a few drops of saturated sal ammoniac solution.

### V. *Cyanides.*

34. *Potassium cyanide (white prussiate of potash).*—For electro-plating purposes pure potassium cyanide with 98 to 99 per cent., as well as that containing 80, 70 and 60 per cent., is used, whilst for pickling the preparation with 45 per cent. is employed. For the preparation of alkaline copper and brass baths, as well as silver baths, the pure 98 to 99 per cent. product is generally employed. However, for preparing gold baths the 60 per cent. article is mostly preferred, because the potash present in all potassium cyanide varieties with a lower content renders fresh baths more conductive. However, gold baths may also be prepared with 98 per cent. potassium cyanide without fear of injury to the efficiency of the baths, while, under ordinary circumstances, a preparation with less than 98 per cent. may safely be used for the rest of the baths. However, when potassium cyanide has to be added to the baths, as is from time to time necessary, only the pure preparation free from potash should be used, because the potash contained in the inferior qualities gradually thickens the bath too much.

No product is more important to the electro-plater than potassium cyanide. The pure 98 to 99 per cent. product is a white transparent crystalline mass, the crystalline structure being plainly perceptible upon the fracture. In a dry state it is odorless, but when it has absorbed some moisture it has a strong smell of prussic acid. It is readily soluble in water, and should be dissolved in *cold* water only, since when poured into hot water it is partially decomposed, which is recognized by the appearance of an odor of ammonia. Potassium cyanide solution in cold water may, however, be boiled for a short time without suffering essential decomposition. Potassium cyanide must be kept in well-closed vessels, since when exposed to the air it

becomes deliquescent, and is decomposed by the carbonic acid of the air, whereby potassium carbonate is formed while prussic acid escapes. It is a deadly poison and must be used with the utmost caution. Potassium cyanide with 80, 70, 60 or 45 per cent. forms a gray-white to white mass with a porcelain-like fracture. A pale gray coloration is not a proof of impurities, it being due to somewhat too high a temperature in fusing. These varieties are found in commerce in irregular lumps or in sticks, the use of the latter offering no advantage. Their behavior towards the air and in dissolving is the same as that of the pure product.

*Recognition.*—By the bitter-almond smell of the solution. By mixing potassium cyanide solution with ferric chloride and then with hydrochloric acid until the latter strongly predominates, a precipitate of Berlin blue is formed.

The pure salt free from potash does not effervesce on adding dilute acid, which is, however, the case with the inferior qualities.

To facilitate the use of potassium cyanide with a different content than that given in a formula for preparing a bath, the following table is here given:

Potassium cyanide with				
98 per cent.	80 per cent.	70 per cent.	60 per cent.	45 per cent.
By weight.	By weight.	By weight.	By weight.	By weight.
1 part =	1.230 parts =	1.400 parts =	1.660 parts =	2.180 parts.
0.820 " =	1 " =	1.143 " =	1.333 " =	1.780 "
0.714 " =	0.875 part =	1. part =	1.170 " =	1.550 "
0.615 " =	0.750 " =	0.857 " =	1. part =	1.450 "
0.460 " =	0.562 " =	0.643 " =	0.750 " =	1 part.

35. *Copper cyanides.*—There is a cuprous and a cupric cyanide; that used for electro-plating purposes being a mixture of both. It is a green-brown powder, which should not be dried,

since in the moist state it dissolves more readily in potassium cyanide. It is only used as a double salt, *i. e.*, in combination with potassium cyanide in the preparation of copper, brass, tombac, and red gold baths.

*Recognition.*—By evaporating a piece of copper cyanide the size of a pea, or its solution in hydrochloric acid, to dryness in a water bath, wherein care must be taken not to inhale the vapors, and dissolving the residue in water, a green-blue solution is obtained which acquires a deep blue color by the addition of ammonia in excess.

36. *Zinc cyanide (hydrocyanate of zinc, prussiate of zinc).*—A white powder insoluble in water, but soluble in potassium cyanide, ammonia and the alkaline sulphites. The fresher it is, the more readily it dissolves, the dried product dissolving with difficulty. Its solution in potassium cyanide is used for brass baths.

*Recognition.*—By evaporating zinc cyanide, or its solution, with an excess of hydrochloric acid in the water bath, zinc chloride remains behind, which is recognized by the same reaction given under zinc chloride.

37. *Silver cyanide (prussiate, or hydrocyanate of silver).*—A white powder which slowly becomes black when exposed to light. It is insoluble in water and cold acids, which, however, will dissolve it with the aid of heat. At 750° F., it melts to a dark red fluid, which, on cooling, forms a yellow mass with a granular structure. It is readily dissolved by potassium cyanide, but is only slightly soluble in ammonia, differing in this respect from silver chloride. It forms a double salt with potassium cyanide, and as such is employed in the preparation of silver baths.

38. *Potassium ferro-cyanide (yellow prussiate of potash).*—It occurs in the shape of yellow semi-translucent crystals with mother-of-pearl lustre, which break without noise. Exposed to heat they effloresce, losing their water of crystallization, and crumbling to a yellowish-white powder. For the solution of 1 part of the salt, 4 of water of medium temperature are required,

the solution exhibiting a pale yellow color. It precipitates nearly all the metallic salts from their solutions, some of the precipitates being soluble in an excess of the precipitating agent. This salt is not poisonous. It serves for the preparation of silver and gold baths; its employment, however, offering no advantages over potassium cyanide except its non-poisonous properties be considered as such.

*Recognition.*—When the yellow solution is mixed with ferric chloride a precipitate of Berlin blue is formed.

## VI. Carbonates.

39. *Potassium carbonate (potash).*—It is found in commerce in gray-white, bluish, yellowish pieces, the colorations being due to admixtures of small quantities of various metallic oxides. When pure it is in the form of a white powder or in pieces the size of a pea. The salt, being very deliquescent, has to be kept in well-closed receptacles. It is readily soluble, and, if pure, the solution in distilled water must be clear. It serves as an addition to some baths, and in an impure state for freeing objects from grease.

*Recognition.*—The solution effervesces on the addition of hydrochloric acid. The solution neutralized with hydrochloric acid gives with platinum chloride a heavy yellow precipitate of platinic potassium chloride, provided the solution be not too dilute.

40. *Acid potassium carbonate or monopotassic carbonate, commonly called bicarbonate of potash.*—Colorless transparent crystals, which at a medium temperature dissolve to a clear solution in 4 parts of water. It is not deliquescent; however, on boiling its solution it loses carbonic acid, and contains then only potassium carbonate. It is employed for the preparation of certain baths for gilding by simple immersion.

41. *Sodium carbonate (washing soda).*—It occurs in commerce as crystallized or calcined soda of various degrees of purity. The crystallized product forms colorless crystals or masses of crystals, which, on exposure to air, rapidly effloresce



and crumble to a white powder. By heating, the crystals also lose their water, a white powder, the so-called calcined soda, remaining behind. Soda dissolves readily in water, and serves as an addition to copper and brass baths, for the preparation of metallic carbonates, and for freeing objects from grease, the ordinary impure soda being used for the latter purpose.

The directions for additions of sodium carbonate to baths generally refer to the crystallized salt. If calcined soda is to be used instead, 0.4 part of it will have to be taken for 1 part of the crystallized product.

42. *Sodium bicarbonate (baking powder)*.—A dull white powder soluble in 10 parts of water of 68° F. On boiling, the solution loses one-half of its carbonic acid, and then contains sodium carbonate only.

43. *Calcium carbonate (marble, chalk)*.—When pure it forms a snow-white crystalline powder, a yellowish color indicating a content of iron. It is insoluble in water, but soluble, with effervescence, in hydrochloric, nitric and acetic acids. In nature, calcium carbonate occurs as marble, limestone, chalk.

In the form of *whiting* (ground chalk carefully freed from all stony matter) it is used for the removal of an excess of acid in acid copper baths, and mixed with burnt lime as an agent for freeing objects from grease.

44. *Copper carbonate*.—Occurs in nature as malachite and allied minerals. The artificial carbonate is an azure-blue substance, insoluble in water, but soluble, with effervescence, in acids. Copper carbonate precipitated from copper solution by alkaline carbonates has a greenish color. Copper carbonate is employed for copper and brass baths, and for the removal of an excess of acid in acid copper baths.

*Recognition*.—Dissolves in acids with effervescence; on dipping a ribband of bright sheet-iron in the solution, copper separates upon the iron. On compounding the solution with ammonia in excess, a deep blue coloration is obtained.

45. *Zinc carbonate*.—A white powder, insoluble in water. The product obtained by precipitating a zinc salt with alkaline

carbonates is a combination of zinc carbonate with zinc oxyhydrate. It serves for brass baths in connection with potassium cyanide.

*Recognition.*—In a solution in hydrochloric acid, which is formed with effervescence, according to the reactions given under zinc chloride (27).

46. *Nickel carbonate.*—A pale apple-green powder, insoluble in water, but soluble, with effervescence, in acids. It is employed for neutralizing nickel baths which have become acid.

*Recognition.*—In hydrochloric acid, it dissolves, with effervescence, to a green fluid. By the addition of a small quantity of ammonia, nickel oxyhydrate is precipitated, which, by adding ammonia in excess, is redissolved, the solution showing a blue color.

47. *Cobalt carbonate.*—A reddish powder, insoluble in water, but soluble in acids, the solution forming a red fluid.

## VII. Sulphates and Sulphites.

48. *Sodium sulphate (Glauber's salt).*—Clear crystals of a slightly bitter taste, which effloresce by exposure to the air. They are readily soluble in water. On heating, the crystals melt in their water of crystallization, and when subjected to a red heat, calcined Glauber's salt remains behind. It is used as an addition to some baths.

49. *Ammonium sulphate.*—It forms a neutral colorless salt, which is constant in the air, readily dissolves in water, and evaporates on heating. It serves as a conducting salt for nickel, cobalt and zinc baths.

*Recognition.*—By its evaporating on heating. A concentrated solution compounded with platinic chloride gives a yellow precipitate of platoso-ammonium chloride, while a solution mixed with a few drops of hydrochloric acid gives with barium chloride a precipitate of barium sulphate.

50. *Ammonium-potassium sulphate (potash-alum).*—Colorless crystals or pieces of crystals with an astringent taste. It is soluble in water, 12 parts of it dissolving in 100 parts of water

at the ordinary temperature. On heating, the crystals melt, and are converted into a white spongy mass, the so-called burnt alum. Potash-alum serves for the preparation of zinc baths and for brightening the color of gold.

*Recognition.*—On adding sodium phosphate to the solution of this salt a jelly-like precipitate of aluminium phosphate is formed, which is soluble in caustic potash, but insoluble in acetic acid.

51. *Ammonium-alum* is exactly analogous to the above, the potassium sulphate being simply replaced by ammonium sulphate. It is for most purposes interchangeable with potash-alum. On exposing ammonium-alum to a red heat, the ammonium sulphate is lost, pure alumina remaining behind. Ammonium-alum is used for preparing a bath for zincking iron and steel by immersion.

*Recognition.*—The same as potash-alum. On heating the comminuted ammonium-alum with potash lye, an odor of ammonia becomes perceptible.

52. *Ferrous sulphate (sulphate of iron, protosulphate of iron, copperas, green vitriol).*—Pure ferrous sulphate forms bluish-green transparent crystals of a sweetish astringent taste, which readily dissolve in water, and effloresce and oxidize in the air. The crude article forms green fragments frequently coated with a yellow powder. It generally contains, besides ferrous sulphate, the sulphate of copper and of zinc, as well as ferric sulphate. Ferrous sulphate is employed in the preparation of iron baths, and for the reduction of gold from its solutions.

*Recognition.*—By compounding the green solution with a few drops of concentrated nitric acid, a black-blue ring is formed on the point of contact. On mixing the lukewarm solution with gold chloride, gold is separated as a brown powder, which by rubbing acquires the lustre of gold.

53. *Iron-ammonium sulphate.*—Green crystals which are constant in the air and do not oxidize as readily as green vitriol. 100 parts of water dissolve 16 parts of this salt. It is used for the same purposes as green vitriol.

54. *Copper sulphate (cupric sulphate, blue vitriol, or blue cop-*

*peras*).—It forms large blue crystals, of which 190 parts of cold water dissolve about 40 parts, and the same volume of hot water about 200 parts. Blue vitriol which does not possess a pure blue color, but shows a greenish lustre, is contaminated with green vitriol, and should not be used for electro-plating purposes. Blue vitriol serves for the preparation of alkaline copper and brass baths, acid copper baths, etc.

*Recognition*.—By its appearance, as it can scarcely be mistaken for anything else. A content of iron is recognized by boiling blue vitriol solution with a small quantity of nitric acid, and adding spirits of sal ammoniac in excess; brown flakes indicate iron.

55. *Cuprous sulphite*.—A brownish red crystalline powder formed by treating cuprous hydrate with sulphurous acid solution. It is insoluble in water, but readily soluble in potassium cyanide, with only slight evolution of cyanogen. It serves for the preparation of alkaline copper baths in place of basic acetate of copper (*verdigris*), blue vitriol, or cuprous oxide.

56. *Zinc sulphate (white vitriol)*.—It forms small colorless prisms of a harsh metallic taste, which readily oxidize on exposure to the air. By heating the crystals melt, and by heating to a red heat they are decomposed into sulphurous acid and oxygen, which escape, while zinc oxide remains behind as residue. 100 parts of water dissolve about 50 parts of zinc sulphate in the cold, and nearly 100 parts at the boiling-point. Zinc sulphate is employed for the preparation of brass and zinc baths, as well as for matt pickling.

*Recognition*.—By mixing zinc sulphate solution with acetic acid and conducting sulphuretted hydrogen into the mixture, a white precipitate of zinc sulphide is formed. A slight content of iron is recognized by the zinc sulphate solution, made alkaline by ammonia, giving with ammonia sulphide a somewhat colored precipitate instead of a pure white one. However, a slight content of iron does no harm.

57. *Nickel sulphate*.—Beautiful dark green crystals, readily soluble in water, the solution exhibiting a green color. On



heating the crystals to above  $536^{\circ}$  F., yellow anhydrous nickel sulphate remains behind. Like the double salt described below, it serves for the preparation of nickel baths and for coloring zinc.

*Recognition.*—By compounding the solution with ammonia the green color passes into blue. Potassium carbonate precipitates pale green basic nickel carbonate, which dissolves on adding ammonia in excess, the solution showing a blue color. A content of copper is recognized by the separation of black-brown copper sulphide on introducing sulphuretted hydrogen into the heated solution previously strongly acidulated with hydrochloric acid.

58. *Nickel-ammonium sulphate.*—It forms green crystals of a somewhat paler color than nickel sulphate. This salt dissolves with more difficulty than the preceding, 100 parts of water dissolving only 5.5 parts of it. It is used for the same purposes as the nickel sulphate, and is also recognized in the same manner. The following reaction serves for distinguishing it from nickel sulphate: By heating nickel sulphate in concentrated solution with the same volume of strong potash or soda lye, no odor of ammonia is perceptible, while nickel-ammonium sulphate evolves ammoniacal gas which forms dense clouds on a glass rod moistened with hydrochloric acid.

59. *Cobalt sulphate.*—Crimson crystals of a sharp metallic taste. They are constant in the air and readily dissolve in water, the solution showing a red color. By heating, the crystals lose their water of crystallization without, however, melting, and become thereby transparent and rose-colored. The salt is used for cobalt baths for the electro-deposition of cobalt and for cobalting by contact.

*Recognition.*—In the presence of ammoniacal salts, caustic potash precipitates a blue basic salt, which, on heating, changes to a rose-colored hydrate and, by standing for some time in the air, to a green-brown hydrate. By mixing a concentrated solution of the salt strongly acidulated with hydrochloric acid with solution of potassium nitrate, a reddish-yellow precipitate is formed.

60. *Cobalt-ammonium sulphate*. This salt forms crystals of the same color as cobalt sulphate, which, however, dissolve more readily in water.

61. *Sodium sulphite and bisulphite*.—a. *Sodium sulphite*. Clear, colorless, and odorless crystals, which are rapidly transformed into an amorphous powder by efflorescence. The salt readily dissolves in water, the solution showing a slight alkaline reaction due to a small content of sodium carbonate. It is employed in the preparation of gold, brass, and copper baths, for silvering by immersion, etc.

*Recognition*.—The solution when mixed with dilute sulphuric acid has an odor of burning sulphur.

b. *Sodium bisulphite*.—Small crystals, or more frequently in the shape of a pale yellow powder with a strong odor of sulphurous acid and readily soluble in water. The solution shows a strong acid reaction and loses sulphurous acid in the air. It is employed in the preparation of alkaline copper and brass baths.

Both the sulphite and bisulphite must be kept in well-closed receptacles, as by the absorption of atmospheric oxygen they are converted to sulphate.

### VIII. Nitrates.

62. *Potassium nitrate (saltpetre, nitre)*.—It forms large, prismatic crystals, generally hollow, but also occurs in commerce in the form of a coarse powder, soluble in 4 parts of water at a medium temperature. The solution has a bitter, saline taste and shows a neutral reaction. Potassium nitrate melts at a red heat, and on cooling congeals to an opaque, crystalline mass. It is employed in the preparation of desilvering pickle and for producing a matt lustre upon gold and gilding. For these purposes it may, however, be replaced by the cheaper *sodium nitrate*, sometimes called *cubic nitre* or *Chile saltpetre*.

*Recognition*.—A small piece of coal when thrown upon melting saltpetre burns fiercely. When a not too dilute solution of saltpetre is compounded with solution of potassium bitartrate

saturated at the ordinary temperature, a crystalline precipitate of tartar is formed.

63. *Sodium nitrate (cubic nitre or Chile saltpetre)*.—Colorless crystals, deliquescent and very soluble in water; the solution shows a neutral reaction. It is used for the same purposes as potassium nitrate.

64. *Mercurous nitrate*.—It forms small, colorless crystals, which are quite transparent and slightly effloresce in the air. On heating they melt and are transformed, with the evolution of yellow-red vapors, into yellow-red mercuric oxide, which, on further heating, entirely evaporates. With a small quantity of water, mercurous nitrate yields a clear solution. By the further addition of water it shows a milky turbidity, which, however, disappears on adding nitric acid. It is employed for quickening the zincs of the elements, and the objects previous to silvering, and for brightening gilding. For the same purpose is also used:

65. *Mercuric nitrate (nitrate of mercury)*. This salt is obtained with difficulty in a crystallized form. It is generally sold in the form of an oily, colorless liquid which, in contact with water, separates a basic salt. This precipitate disappears upon the addition of a few drops of nitric acid, and the liquid becomes clear.

*Recognition*.—A bright riband of copper dipped in solution of mercurous or mercuric nitrate becomes coated with a white amalgam, which disappears upon heating.

66. *Silver nitrate (lunar caustic)*.—This salt is found in commerce in three forms: either as crystallized nitrate of silver in thin, rhombic, and transparent plates; or in amorphous, opaque, and white plates of fused nitrate; or in small cylinders of a white, or gray, or black color, according to the nature of the mould employed, in which form it constitutes the lunar caustic for surgical uses. For our purposes only the pure, crystallized product, free from acid, should be employed. The crystals dissolve readily in water. In making solutions of this and other silver salts, only distilled water should be used; all other

waters, owing to the presence of chlorine, produce a cloudiness or even a distinct precipitate of silver chloride. When subjected to heat the crystals melt to a colorless, oily fluid, which, on cooling, congeals to a crystalline mass. Silver nitrate is employed in the preparation of chloride and cyanide of silver for silver baths. The solution in potassium cyanide may also be used for silver baths. The alcoholic solution is employed for metallizing moulds.

*Recognition.*—Hydrochloric acid and common salt solution precipitate from silver nitrate solution silver chloride, which becomes black on exposure to the light, and is soluble in ammonia.

#### IX. *Phosphates and Pyrophosphates.*

67. *Sodium phosphate.*—Large, clear crystals, which readily effloresce, and whose solution in water shows an alkaline solution. It is employed in the preparation of gold baths and for the production of metallic phosphates for soldering.

*Recognition.*—The dilute solution compounded with silver nitrate yields a yellow precipitate of silver phosphate.

68. *Sodium pyrophosphate.*—It forms white crystals, which are not subject to efflorescence, and are soluble in 6 parts of water at a medium temperature; the solution shows an alkaline reaction. Sodium pyrophosphate also occurs in commerce in the form of an anhydrous white powder, though it may here be said that the directions for preparing baths refer to the crystallized salt. It is employed in the preparation of gold, nickel-bronze, and tin baths.

*Recognition.*—The dilute solution compounded with silver nitrate yields a *white* instead of a *yellow* precipitate.

69. *Ammonium phosphate.*—A colorless crystalline powder quite readily soluble in water; the solution should be as neutral as possible. A salt smelling of ammonia, as well as one showing an acid reaction, should be rejected. It is employed in the preparation of platinum baths.



X. *Salts of Organic Acids.*

70. *Potassium bitartrate (cream of tartar).*—The pure salt forms small transparent crystals, which have an acid taste, and are slightly soluble in water. The commercial crude tartar or *argol*, which is a by-product in the wine industry, forms gray or dirty red crystalline crusts. In finely powdered state, purified tartar is called *cream of tartar*. It is employed for the preparation of the whitening silver baths, for those of tin, and for the silvering paste for silvering by friction.

71. *Potassium-sodium tartrate (Rochelle or Seignette salt).*—Clear colorless crystals, constant in the air, of a cooling bitter saline taste, and soluble in 2.5 parts of water of a medium temperature. The solution shows a neutral reaction. This salt is employed in the preparation of copper baths free from cyanide, as well as of nickel and cobalt baths, which are to be decomposed in the single cell apparatus.

*Recognition.*—By the addition of acetic acid the solution yields an abundant precipitate of tartar.

72. *Antimony-potassium tartrate (tartar emetic).*—A white crystalline substance, of which 100 parts of cold water dissolve 5 parts, while a like volume of hot water dissolves 50 parts. The solution shows a slightly acid reaction. The only use of this salt is for the preparation of antimony baths.

*Recognition.*—The solution of the salt compounded with sulphuric, nitric, or oxalic acid yields a white precipitate, insoluble in an excess of the cold acid. Sulphuretted hydrogen imparts to the dilute solution a red color. Hydrochloric acid effects a precipitate, which is redissolved by the acid in excess.

73. *Copper acetate (verdigris).*—It is found in the market in the form of dark green crystals showing an acid reaction, or of a neutral bright green powder.

The crystallized copper acetate forms opaque dark green prisms, which readily effloresce, becoming thereby coated with a pale green powder. They dissolve with difficulty in water, but readily in ammonia, forming a solution of a blue color. They dissolve readily also in potassium cyanide and alkaline sulphites.

The neutral copper acetate forms a blue-green crystalline powder, imperfectly soluble in water, but readily soluble in ammonia, forming a solution of a blue color.

Copper acetate is used for preparing copper and brass baths, for the production of artificial patinas, for coloring, gilding, etc.

74. *Lead acetate (sugar of lead).*—Colorless lustrous prisms or needles of a nauseous sweet taste and poisonous. The crystals effloresce in the air, melt at  $104^{\circ}$  F., and are readily soluble in water, yielding a slightly turbid solution. Lead acetate is employed for preparing lead baths (Nobili's rings) and for coloring copper and brass.

*Recognition.*—By compounding lead acetate solution with potassium chromate solution, a heavy yellow precipitate of lead chromate is formed.

75. *Sodium citrate.*—Colorless crystals, presenting a moist appearance, which are readily soluble in water; the solution should show a neutral reaction. This salt is employed in the preparation of the platinum bath according to Böttger's formula, and as conducting salt for nickel and zinc baths.

#### B. VARIOUS APPARATUS AND INSTRUMENTS.

*Glass balloons and flasks.*—These are spheres of thin blown glass, Fig. 153, with necks of various dimensions in length and diameter. They are employed for heating acids, dissolving metals, and a great many other uses. They should be placed upon triangular supports of iron and at a certain distance from the fire, from the direct action of which they are to be protected by the intervention of a piece of wire gauze or its equivalent. The thinner they are the more easily they bear sudden changes of temperature. They are preferable to porcelain evaporating dishes for dissolving gold, because there is much less danger of losing a part of the product by spurting.

FIG. 153.



*Evaporating dishes or capsules.*—These are usually vessels of porcelain, and are intended to bear a high temperature. The

best are thin and uniformly so. Like glass flasks, they should be supported above the fire upon an iron stand and wire gauze. As far as practicable they should be gradually heated and cooled. When taken from the fire they should be placed upon rings made of plaited straw. They are made with or without lips, and some have a socket for a wooden handle. Glass evaporating dishes are not durable.

*Glass jars.*—These are glass vessels, generally cylindrical, closed at one end, and of different capacities.

They are employed for small gilding, silvering, and electroplating baths in the cold. They are handy and serviceable for amateurs, because their transparency permits the progress of the operation to be observed at all times.

*Crucibles.*—These are vessels, the shape of which is generally an inverted truncated cone, Fig. 155, the smaller end being closed and the larger open. Sometimes the opening is triangular.

FIG. 154.



Crucibles are made of many kinds of materials; metals, refractory clay, stoneware, porcelain, plumbago or graphite, etc. They are generally provided with a cover of the same material, and are raised above the grate bars of the furnace by means of bricks or cylinders of clay. Metallic crucibles may be heated rapidly, but the others require to have their temperature raised gradually and carefully. They are employed for the preparation of many salts, for the fusion of metals, etc. Non-metallic crucibles are rarely used for more than one operation.

*Hydrometers.*—These are glass instruments resembling thermometers in outward appearance, but having a large bulb near the bottom. They are used for testing the specific gravity of liquids, or, in other words, to test their density as compared with that of pure water. The liquid to be tested may be placed in a narrow glass jar together with the hydrometer, or may be contained in any other vessel. The instrument floats in the liquid to be tested, with its bulb below the surface and its stem standing above the surface. This stem is graded into degrees

similar to that of a thermometer, and shows the depth of the bulb beneath the surface. In pure water the bulb sinks down to the 0° mark, or to 1.000 as marked on some scales, 1.000 being taken to represent the density of water at a temperature of 60° F. As the density of water increases by the addition of salts or of liquids having a greater density than water, the bulb is forced upwards, and the scale then registers so many degrees greater density than water.

Three differently graduated hydrometers are in use, viz., hydrometers graded to read direct the specific gravity of liquids in comparison with that of water, taking this as represented by 1.000; hydrometers graded by a scale adopted by Mr. W. Twaddell, and known as Twaddell's hydrometers; and hydrometers graded by a scale adopted by M. Baumé, and named Baumé's hydrometers. The difference between the three gradings is shown in the following table:—

*Table showing the readings of different hydrometers.*

Specific gravity.	Baumé.	Twaddell.	Specific gravity.	Baumé.	Twaddell.
.817°	40°	—	1.250°	—	50°
.827	38	—	1.263	30°	—
.837	36	—	1.300	—	60
.847	34	—	1.321	35	—
.856	32	—	1.350	—	70
.871	30	—	1.385	40	—
.880	28	—	1.400	—	80
.892	26	—	1.450	—	90
.903	24	—	1.454	45	—
.915	22	—	1.500	—	100
.928	20	—	1.532	50	—
.942	18	—	1.550	—	110
.955	16	—	1.600	—	120
.970	14	—	1.618	55	—
.985	12	—	1.650	—	130
1.000	0° or 10	0°	1.700	—	140
1.036	5	—	1.714	60	—
1.050	—	10	1.750	—	150
1.075	10	—	1.800	—	160
1.100	—	20	1.823	65	—
1.116	15	—	1.850	—	170
1.150	—	30	1.900	—	180
1.161	20	—	1.946	70	—
1.200	—	40	1.950	—	190
1.210	25	—			



It will be seen that every degree Twaddell represents  $0.005^{\circ}$  in the specific gravity hydrometer, and every  $10^{\circ}$  represents 0.050. To convert degrees Baumé into readings showing direct specific gravity, subtract the readings on Baumé's scale from the number 144, and divide this by the difference. For example,  $144 - 66 = 78 = 1.846^{\circ}$ , the specific gravity of a liquid registering  $66^{\circ}$  on a Baumé hydrometer. Baumé has one hydrometer for liquids lighter than water (the readings of which are given in the first 16 sets of figures in the foregoing table), and one for liquids heavier than water.

**Filters.**—Filtering a solution, a bath, or any other liquor, consists in causing it to pass through a permeable substance, the pores or meshes of which are sufficiently closed to retain all the undissolved substances, which are thus separated from the liquid part.



Filters are of very different materials and shapes. Cloth, muslin, etc., are coarse filters or strainers, made in the form of pockets. Their filtering power is considerably improved by covering them with a layer of sand, wool, boneblack, etc. These latter substances themselves, properly supported, will act as filters.

Felted wool (generally rabbit's hair) is made in the shape of a conical pocket (Fig. 155), but is suited only for neutral substances. Alkalies destroy it rapidly.

Concentrated acids are filtered through *amianthus*, or *asbestos*, compressed in the neck of a glass funnel upon broken fragments of glass.



The most useful filtering material, however, is unsized paper. This filter (Fig. 156) is prepared by folding diagonally a square piece of porous paper, which thus prepared forms a triangle.

This is again folded in half. Then, beginning at one edge, smaller folds are made alternately to the right and to the left, but all converging towards the point, like a fan. The filter is now partially opened, trimmed on top, and intro-

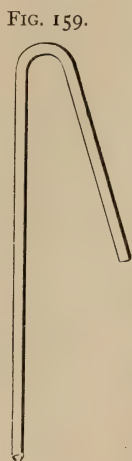
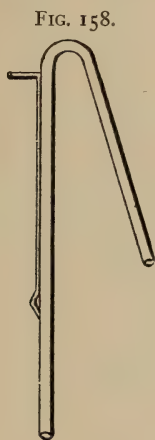
duced into the funnel, care being had that all the projecting edges rest against it.

If it be feared that the filter will not resist the weight of the liquid, the point is twisted to the left or to the right, and while it is still held between two fingers of the left hand, the whole filter is inverted, so that the inward folds become the outward ones. A filter with such a rounded point is better supported in the funnel, and filters more rapidly.



This method is preferable for rapid filtration; but if it is desired to recover precipitates, the filter represented by Fig. 157 is more suitable. A circular sheet of paper is twice doubled up, and by carefully opening it three thicknesses of paper are laid on one side, leaving one single thickness on the other side.

*Siphons.*—The most simple and handy siphon, in many cases, is a piece of lead pipe bent so as to have two unequal branches,



the smaller of which plunges into the liquid to be drawn off. A section of India-rubber tube may be employed for similar purposes.

But as these materials may be chemically acted upon by

various solutions, glass siphons are used, with or without a suction tube (Figs. 158 and 159).

For siphoning corrosive solutions which cannot be touched with the fingers, a siphon with a suction tube is used (Fig. 158). The shorter leg is plunged into the liquid and the longer one closed with the finger or an India-rubber pad pressed against it; then, with the mouth, suction should be carefully applied at the lateral suction tube until the liquid fills the longer leg.

If there be any danger of inhaling a poisonous vapor, the action of the mouth may be replaced by an India-rubber ball fastened to the suction tube. The longer branch of the siphon is closed as before, and the ball compressed in order to remove the air. By its elasticity the ball resumes its former volume, thus producing a suction which starts the siphon in action.

*Stirring rods.*—These are rods made of various materials, and are employed for mixing together liquids or pastes, or solids with liquids, or various solids in the dry state. Their length and thickness should be suited to the volumes to be mixed.

Suitable stirring rods are those which have no chemical action upon the substances with which they are brought in contact; neither should they become impregnated with them. Rods of glass, stoneware, or porcelain are decidedly the best. Wood and most metals should be avoided, because the former is absorbent and the latter are corroded and easily oxidized.

The operator should always have near at hand a complete assortment of glass stirrers of various sizes, and with fused or rounded ends, in order not to scratch the vessels in which he operates.

# APPENDIX.

## USEFUL TABLES.

*Table of elements with their symbols, atomic weights, and specific gravities.*

Name.	Sym- bol.	Atomic weight.	Specific gravity.	Name.	Sym- bol.	Atomic Weight.	Specific gravity.
Aluminium . . . .	Al	27.1	2.67	Molybdenum . . . .	Mo	96.0	8.60
Antimony . . . .	Sb	120.4	6.72	Nickel . . . . .	Ni	58.7	8.6
Arsenic . . . . .	As	75.0	5.63	Niobium . . . . .	Nb	93.7	6.67
Barium . . . . .	Ba	137.4	4.00	Nitrogen . . . . .	N	14.04	0.972
Beryllium . . . .	Be	9.3	2.10	Osmium . . . . .	Os	191.0	21.3
Bismuth . . . . .	Bi	208.11	9.799	Oxygen . . . . .	O	16.0	1.088
Boron . . . . .	B	11.0	2.68	Palladium . . . . .	Pd	107.0	1.8
Bromine . . . . .	Br	79.95	2.97	Phosphorus . . . .	P	31.0	1.84
Cadmium . . . . .	Cd	112.4	8.67	Platinum . . . . .	Pt	194.9	21.15
Cæsium . . . . .	Cs	133.0	—	Potassium . . . . .	K	39.11	8.805
Calcium . . . . .	Ca	40.1	3.10	Rhodium . . . . .	Rh	103.0	12.10
Carbon . . . . .	C	12.0	3.50	Rubidium . . . . .	Rb	85.4	1.50
Cerium . . . . .	Ce	139.0	—	Ruthenium . . . . .	Ru	101.7	11.40
Chloride . . . . .	Cl	35.5	2.45	Selenium . . . . .	Se	79.2	4.28
Chromium . . . . .	Cr	52.1	6.81	Silicium . . . . .	Si	28.4	2.49
Cobalt . . . . .	Co	59.00	8.50	Silver . . . . .	Ag	107.92	10.50
Copper . . . . .	Cu	93.7	8.88	Sodium . . . . .	Na	23.05	0.972
Didymium . . . . .	D	95.0	—	Strontium . . . . .	Sr	87.60	2.54
Erbium . . . . .	E	166.0	—	Sulphur . . . . .	S	32.07	2.045
Fluorine . . . . .	F	19.0	—	Tantalum . . . . .	Ta	182.8	10.78
Gold . . . . .	Au	197.2	19.50	Tellurium . . . . .	Te	127	6.18
Hydrogen . . . .	H	1.003	0.069	Thallium . . . . .	Tl	204.15	11.86
Indium . . . . .	In	114.0	—	Thorium . . . . .	Th	232.6	7.70
Iodine . . . . .	I	126.85	4.98	Tin . . . . .	Sn	119.0	7.29
Iridium . . . . .	Ir	193.1	21.15	Titanium . . . . .	Ti	48.15	5.30
Iron . . . . .	Fe	55.9	7.70	Tungsten . . . . .	W	184.0	18.40
Lanthanum . . . .	La	138.6	—	Uranium . . . . .	U	239.6	19.40
Lead . . . . .	Pb	206.92	11.38	Vanadium . . . . .	V	51.4	5.50
Lithium . . . . .	Li	7.03	0.59	Yttrium . . . . .	Y	89.0	—
Magnesium . . . .	Mg	24.3	1.74	Zinc . . . . .	Zn	65.4	7.2
Manganese . . . .	Mn	55.0	8.00	Zirconium . . . . .	Zr	90.4	4.20
Mercury . . . . .	Hg	200.0	13.59				



*Table of chemical and electro-chemical equivalents.*

Name of substance.	Sym- bol.	Specific gravity.	Chemical equiva- lent.	Electro- chemical equi- valent. Milligrammes.	Weights decomposed by 1 ampère in 1 hour. In grammes.
Hydrogen .....	H	1	1	0.01036	0.0375
Aluminium .....	Al	2.6	13.7	0.14250	0.5137
Antimony .....	Sb	6.8	122	1.26880	4.5750
Arsenic .....	As	5.7	75	0.78000	2.8125
Cobalt .....	Co	8.7	29.5	0.30680	1.1062
Copper .....	Cu	8.8	31.8	0.33070	1.1925
Gold .....	Au	19.2	98.3	1.02230	3.6862
Iron .....	Fe	7.5	28	0.29120	1.0500
Lead .....	Pb	11.3	103.5	1.07640	3.8812
Nickel .....	Ni	8.6	29.5	0.30680	1.1062
Platinum .....	Pt	21.2	98.6	1.02540	3.6975
Silver .....	Ag	10.5	108	1.12340	4.0500
Tin .....	Sn	7.3	32.7	0.34010	1.2262
Zinc .....	Zn	7.2	59	0.61360	2.2125

With the assistance of this table it can be calculated how long a measured surface has to remain in the bath in order to acquire a deposit of determined weight with the most suitable current-density. Suppose the time is to be determined which a square decimetre of surface has to remain in the nickel bath in order to acquire a deposit of  $\frac{1}{10}$  millimetre thick with a current-density of 0.5 ampère. First calculate the weight of the deposit by multiplying the surface in square millimetres with the thickness and specific gravity. One square decimetre is equal to 10,000 square millimetres, which, multiplied by  $\frac{1}{10}$  millimetre, gives as a product 1000, which multiplied by the specific gravity of nickel—8.6—gives 8600 milligrammes = 8.6 grammes. Since, for the regular deposit per square decimetre, a current density of 0.5 ampère is required, and 1 ampère deposits, according to the above table, 1.1062 grammes in 1 hour,  $\frac{1}{2}$  ampère deposits 0.5331 gramme in 1 hour, and, therefore, about 16 hours will be required for the deposition of 8.6 grammes.

According to this example, the time, for instance, can also be calculated which one, two, or more dozen of knives and forks

or spoons, which are to have a deposit of silver of a determined weight, must remain in the bath when the current-density is known. Suppose 50 grammes of silver are to be deposited upon 1 dozen of spoons, and the most suitable current density is 0.2 ampère per square decimetre; if the surface of 1 spoon represents 1.10 square decimetres, the surface of 1 dozen spoons of equal size is 13.2 square decimetres. Hence, they require  $13.2 \times 0.2 = 2.64$  ampères; now, since 1 ampère deposits in one hour 4.05 grammes of silver, 2.64 ampères deposit in the same time 10.7 grammes of silver, and with this current the dozen spoons must remain about  $4\frac{3}{4}$  hours in the bath for the deposition of 50 grammes of silver upon this surface.

*Table showing the value of equal current volnmes as expressed in ampères per square decimetre, per square foot, and per square inch of electrode surface.*

Ampères per square decimetre.	Ampères per square foot.	Ampères per square inch.	Ampères per square decimetre.	Ampères per square foot.	Ampères per square inch.	Ampères per square decimetre.	Ampères per square foot.	Ampères per square inch.
0.05	0.46	0.0032	0.8	7.43	0.0516	6.20	57.6	0.4
0.054	0.5	0.0035	0.86	8	0.0555	6.46	60	0.4167
0.077	0.72	0.005	0.9	8.36	0.0581	7	65.0	0.4516
0.1	0.93	0.0064	0.93	8.64	0.06	7.53	70	0.4861
0.11	1	0.0069	0.97	9	0.0625	7.75	72.0	0.5
0.15	1.44	0.01	1	9.29	0.0645	8	74.3	0.5161
0.2	1.86	0.0129	1.08	10	0.0694	8.61	80	0.5555
0.22	2	0.0139	1.09	10.28	0.07	9	83.6	0.5866
0.3	2.79	0.0193	1.24	11.52	0.08	9.30	86.4	0.6
0.31	2.88	0.02	1.39	12.96	0.09	9.69	90	0.6250
0.32	3	0.0208	1.55	14.4	0.1	10	92.9	0.6452
0.4	3.71	0.0258	2	18.6	0.1290	10.76	100	0.6944
0.43	4	0.0278	2.15	20	0.1389	10.85	100.8	0.7
0.46	4.32	0.03	3	27.9	0.1935	12.40	115.2	0.8
0.5	4.64	0.0323	3.10	28.8	0.2	13.95	129.6	0.9
0.54	5	0.0348	3.23	30	0.2083	15.50	144.0	1
0.6	5.57	0.0387	4	37.1	0.2581	20	185.8	1.2903
0.62	5.76	0.04	4.30	40	0.2778	21.53	200	1.3889
0.65	6	0.0417	4.60	43.2	0.3	30	278.7	1.9355
0.7	6.50	0.0452	5	46.4	0.3226	31.0	288	2
0.75	7	0.0486	5.38	50	0.3478	32.3	300	2.0833
0.77	7.20	0.05	6	55.7	0.3871	46.5	432.0	3

By this table the current-density may be expressed in

ampères per square decimetre, square foot, or square inch, any of them being given. Thus a current of 1 ampère per square decimetre has the same electrolytic value as one of 9.29 ampères per square foot, or 0.0645 per square inch. To find the value of intermediate numbers, not shown above, add together the various numbers representing the hundreds, tens, units, and decimals of the given quantity. Thus 27.5 ampères per square decimetre ( $= 20 + 7 + 5$ ) are equivalent to  $185.8 + 65 + 4.64 = 255.44$  ampères per square foot, or  $1.2903 + 0.4516 + 0.0323 = 1.7742$  ampères per square inch.

*Table showing the specific electrical resistances\* of different sulphuric acid solutions at various temperatures (Feeming Fenkin).*

Specific gravity of acid.	Temperature (Fahrenheit).							
	32°	39.2°	46.4°	53.6°	60.8°	68°	75.2°	82.4°
1.10	1.37	1.17	1.04	0.92	0.84	0.79	0.74	0.71
1.20	1.33	1.11	0.93	0.79	0.67	0.57	0.49	0.41
1.25	1.31	1.09	0.90	0.74	0.62	0.51	0.43	0.36
1.30	1.36	1.13	0.94	0.79	0.66	0.56	0.47	0.30
1.40	1.69	1.47	1.30	1.16	1.05	0.96	0.89	0.84
1.50	2.74	2.41	2.13	1.89	1.72	1.61	1.32	1.42
1.60	4.32	4.16	3.62	3.11	2.75	2.46	2.21	2.02
1.70	9.41	7.67	6.25	5.12	4.23	3.57	3.07	2.71

*Table showing the specific electrical resistances\* of different copper sulphate solutions at various temperatures (Feeming Fenkin).*

No. of parts of copper sulphate dissolved in 100 parts of water.	Temperatures (Fahrenheit).						
	57.2°	60.8°	64.4°	68°	75.2°	82.4°	86°
8	45.7	43.7	41.9	40.2	37.1	34.2	32.9
12	36.3	34.9	33.5	32.2	29.9	27.9	27.0
16	31.2	30.0	28.9	27.9	26.1	24.6	24.0
20	28.5	27.5	26.5	25.6	24.1	22.7	22.2
24	26.9	25.9	24.8	23.9	22.2	20.7	20.0
28	24.7	23.4	22.1	21.0	18.8	16.9	16.0

\* By the term "specific resistance," in the above tables, is meant the absolute resistance in ohms of a column of the liquid 1 square centimetre in cross-section and 1 centimetre long; in other words, it is the resistance of a cubic centimetre of the liquid. The diminution of resistance accompanying a rise of temperature should be especially marked.

*Table of the electro-motive force of elements.*

Name of element.	Constitution.	Electro-motive force in volts.	Authority.
Wollaston .....	Amalgamated zinc and copper in dilute sulphuric acid (1:12).	$\begin{cases} 0.886 \\ 0.861 \\ 0.719 \end{cases}$	Clark and Sabine. Sprague. De la Rive.
Smee .....	Amalgamated zinc in sulphuric acid; platinized silver, or platinum in sulphuric acid (1:12).	$\begin{cases} 1.098 \\ 1.107 \\ 0.541 \\ 1.192 \end{cases}$	Clark and Sabine. Sprague. De la Rive. Naclari.
Daniell .....	Amalgamated zinc in sulphuric acid (1:14); copper in saturated solution of copper sulphate.	$\begin{cases} 1.079 \\ \text{do.} \\ \text{do.} \\ \text{do.} \end{cases}$	Clark and Sabine. Sprague. De la Rive. Naclari.
do .....	Zinc in dilute sulphuric acid (1:12); copper as above.	$\begin{cases} 0.978 \\ 0.98 \end{cases}$	Clark and Sabine. Du Moncel.
Leclanché .....	Zinc in sal ammoniac, carbon with manganese peroxide in sal ammoniac.	$\begin{cases} 1.481 \\ 1.561 \\ 1.942 \\ 1.259 \end{cases}$	Clark and Sabine. Sprague. De la Rive. Beetz.
do .....	Zinc in solution of common salt; carbon with manganese peroxide in common salt solution.	$\begin{cases} 1.493 \\ 1.360 \\ 1.34 \end{cases}$	Sprague. Naclari. Du Moncel.
Marie Davy .....	Zinc in dilute sulphuric acid (1:12); carbon in mercurous sulphate.	$\begin{cases} 1.524 \\ 1.542 \\ 1.482 \\ 1.440 \end{cases}$	Clark and Sabine. Sprague. Naclari. Du Moncel.
Grove .....	Zinc in dilute sulphuric acid (1:12); platinum in fuming nitric acid.	1.956	Clark and Sabine.
do .....	Zinc as above; platinum in nitric acid of 1.38 sp. gr.	$\begin{cases} 1.524 \\ 1.542 \end{cases}$	Clark and Sabine. Sprague.
Bunsen .....	Zinc as above; carbon in fuming nitric acid.	$\begin{cases} 1.964 \\ 1.95 \end{cases}$	Clark and Sabine. Du Moncel.
do .....	Zinc as above; carbon in nitric acid of 1.38 sp. gr.	$\begin{cases} 1.888 \\ 1.941 \\ 1.880 \end{cases}$	Clark and Sabine. Beetz. Naclari.
do .....	Zinc as above; carbon in bichromate of potassium.	$\begin{cases} 2.028 \\ 1.905 \\ 2.120 \end{cases}$	Clark and Sabine. Sprague. Naclari.
Grenet .....	Zinc and carbon in bichromate of potassium.	1.825	Naclari.



*Table showing the solubility of various substances.*

Substances of which 1 part is soluble	In water		In alcohol of 59° F.
	of 59° F.	of 212° F.	
Alum .....	6.5	0.3	insoluble.
Ammonium carbonate .....	4.0	decomposes	soluble.
Citric acid .....	0.75	0.6	soluble.
Copper sulphate (blue vitriol) .....	5.0	1.3	insoluble.
Ferric chloride .....	0.6	very soluble	soluble.
Ferrous chloride .....	0.8	very soluble	soluble.
Ferrous sulphate (green vitriol) ....	1.5	0.3	insoluble.
Iodine .....	7000	soluble	readily soluble.
Nickel nitrate .....	2.0	very soluble	soluble.
Nickel sulphate .....	3.0	2.0	insoluble.
Potash .....	0.9	very soluble	insoluble.
Potash, caustic .....	0.5	very soluble	soluble.
Potassium cyanide .....	readily soluble	readily soluble	soluble.
Potassium dichromate (red chromate of potash) .....	10	1.2	insoluble.
Sal ammoniac .....	3.0	1.4	sparingly soluble.
Silver, citrate .....	sparingly soluble	sparingly soluble	—
Silver, nitrate .....	0.8	very soluble	1 part at a boiling heat.
Soda ..	1.0	0.3	insoluble.
Soda, caustic .....	2.0	0.5	insoluble.
Sodium bisulphite .....	soluble	soluble	—
Sodium chloride .....	2.8	2.5	60
Sodium sulphite .....	4.0	1.0	insoluble.
Yellow prussiate, of potash .....	4.0	1.0	insoluble.
Zinc chloride .....	0.3	very soluble	1
Zinc sulphate .....	2.0	1.0	insoluble.

*Table Showing the Composition of the Most Usual Alloys and Solders.*

Alloys are combinations or mixtures, effected by the fusion of two or more different metals in definite proportions. The electro-plater employs them so constantly that it is important that he be acquainted with the composition of the most usual alloys, and that he learn the preparation of several of them, which, like the fusible alloys of Darcet, will often be serviceable.

It is, of course, possible to vary *ad infinitum* the mixtures and the proportions of the component metals given in the fol-

lowing table, and thus to arrive at an unlimited number of alloys which, on account of slight differences of color, ductility, sonorousness, etc., have received a great variety of names.\*

1. *Alloys.*

	Copper.	Zinc.	Tin.	Lead.	Nickel.	Bismuth.	Antimony.	Arsenic.	Iron.
	PARTS.								
Argentan, elastic .....	57.4	25	—	—	13	—	—	—	9
Brass for articles worked with the hammer .....	70	30	—	—	—	—	—	—	—
“ for turning .....	66	32	—	2	—	—	—	—	—
“ for decorating purposes .....	60	40	—	—	—	—	—	—	—
“ for sheet .....	75	25	—	—	—	—	—	—	—
Britannia .....	4	—	70.5	—	—	—	25.5	—	—
“ .....	10	6	22	—	—	—	62	—	—
Bronze for bells ..	80	—	20	—	—	—	—	—	—
“ for larger bells .....	78	—	22	—	—	—	—	—	—
“ for smaller bells .....	42	—	58	—	—	—	—	—	—
“ for clocks .....	75	—	25	—	—	—	—	—	—
“ for cymbals .....	80	—	20	—	—	—	—	—	—
“ for gongs .....	100	—	25	—	—	—	—	—	—
“ for medals .....	100	—	8	—	—	—	—	—	—
“ for large ordnance .....	90	—	10	—	—	—	—	—	—
“ for small ordnance .....	93	—	7	—	—	—	—	—	—
“ for statues .....	84	—	16	—	—	—	—	—	—
“ “ .....	84	11	4	1	—	—	—	—	—
“ “ .....	82	—	18	—	—	—	—	—	—
Chrysochalk .....	80	10.5	8	—	—	—	—	—	—
Darcet's fusible alloy .....	—	—	4	4	—	8	—	—	—
“ “ “ .....	—	—	3	5	—	8	—	—	—
“ “ “ .....	—	—	2	3	—	5	—	—	—
German silver .....	50	3.5	—	—	4	—	—	—	—
“ “ .....	53	31.25	—	—	15.75	—	—	—	—
“ “ .....	8	3.5	—	—	3	—	—	—	—
“ “ .....	4	1	—	—	1	—	—	—	—
“ “ .....	55	17	2	—	23	—	—	—	3
Potin (French yellow brass) .....	11.9	24.9	1.2	0.2	—	—	—	—	—
Similor .....	100	12	—	—	—	—	—	—	—
Talmi gold .....	86.6	12.6	2.4	1.2	—	—	—	—	—
Telescope mirrors (reflectors) .....	100	—	50	—	—	—	—	1	—
Tombac ..	80	20	—	—	—	—	—	—	—
“ pale .....	76	24	—	—	—	—	—	—	—
“ red .....	88	12	—	—	—	—	—	—	—
“ resembling gold .....	84	16	—	—	—	—	—	—	—

\* For a full description of alloys and amalgams see “The Metallic Alloys,” edited by W. T. Brannet. Philadelphia. Henry Carey Baird & Co. 1896.

2. *Solders.*a. *Soft Solder.*

Tin.	Lead.	Melts	Tin.	Lead.	Melts
PARTS.		at degrees F.	PARTS.		at degrees F.
I	25	558°	1 $\frac{1}{2}$	I	334°
I	10	541	2	I	340
I	5	511	3	I	356
I	3	482	4	I	365
I	2	441	5	I	378
I	I	370	6	I	381

b. *Hard Solder.*

	Brass.	Zinc.	Tin.
	PARTS.		
Very refractory.....	85.42	12.58	—
“ “.....	7	I	—
Refractory.....	3	I	—
“ “.....	4	I	—
Readily fusible.....	5	2	—
“ “.....	5	4	—
Half white.....	12	5	I
“ “.....	44	20.	2
White.....	40	2	8
“ “.....	22	2	4
“ “.....	18	12	30
Very ductile.....	78.25	17.25	—

c. *Silver Solder.*

	Silver.	Copper.	Brass.	Tin.	Zinc.
	PARTS.				
Brass silver solder.....	I	—	I	—	—
Hard silver solder.....	4	I	—	—	—
Very hard solder.....	40	10	—	—	—
Middling hard solder.....	40	10	40	10	—
Soft silver solder.....	32	—	32	2	—
Silver solder for cast iron.....	20	30	—	—	10
Silver solder for steel.....	30	10	—	—	—

d. *Gold Solder.*

	Gold.	Silver.	Copper.	Zinc.
	PARTS.			
Hard solder for fineness 750.....	9	2	1	—
Soft “ “ “ 750.....	12	7	3	—
Solder for fineness 583.....	3	2	1	—
“ “ “ 583.....	2	0.5	0.5	—
“ “ “ less than 583 .....	1	2	1	—
“ “ “ “ “ “ .....	1	2	—	—
“ “ “ “ “ “ .....	1	—	2	—
Solder readily fusible .....	11.94	54.74	28.17	5.01
“ “ “ for yellow gold.....	10	5	—	1

*Table of the melting-points of some metals.*

Metals.	Degrees Fahrenheit.	Metals.	Degrees Fahrenheit.
Tin .....	458.6	Gold .....	2372
Lead .....	599.4	Iron, crude .....	2912 to 3092
Zinc .....	773.6	Nickel .....	2912
Antimony .....	809.6	Steel .....	3092 to 3452
Brass .....	1859	Iron, bar .....	3452 to 3812
Copper .....	1994		

*Table of high temperatures.*

Description.	Degrees Fahrenheit.	Description.	Degrees Fahrenheit.
Incipient red heat .....	977	An orange-red heat .....	1700
A red heat .....	980	A bright red heat .....	1873
A dull red heat visible in daylight.....	1000	A dull white heat .....	1996
Heat of a common fire ....	1140	A white heat .....	3000
A full red heat.....	1200	Heat of a good blast furnace.....	3300
Dull red heat .....	1310		

*Table of the specific gravity and content of solutions of potassium carbonate at 57.2° Fahrenheit, according to Gerlach.*

Potassium carbonate, per cent.	Specific gravity.	Potassium carbonate, per cent.	Specific gravity.	Potassium carbonate, per cent.	Specific gravity.
2	1.01829	20	1.19286	38	1.39476
4	1.03658	22	1.21402	40	1.41870
6	1.05513	24	1.23517	42	1.44338
8	1.07396	26	1.25681	44	1.46807
10	1.09278	28	1.27893	46	1.49314
12	1.11238	30	1.30105	48	1.51861
14	1.13199	32	1.32417	50	1.54408
16	1.15200	34	1.34729	52	1.57048
18	1.17243	36	1.37082	52.024	1.57079



*Table showing the specific gravity of sulphuric acid at 59° F., according to Kolb.*

Degrees Baumé.	Specific gravity.	100 parts by weight contain		One litre contains in kilogrammes.		Degrees Baumé.	Specific gravity.	100 parts by weight contain		One litre contains in kilogrammes	
		SO <sub>3</sub> .	H <sub>2</sub> SO <sub>4</sub> .	SO <sub>3</sub> .	H <sub>2</sub> SO <sub>4</sub> .			SO <sub>3</sub> .	H <sub>2</sub> SO <sub>4</sub> .	SO <sub>3</sub> .	HSO <sub>4</sub> .
0	1.000	0.7	0.9	0.007	0.009	34	1.308	32.8	40.2	0.429	0.526
1	1.007	1.5	1.9	0.015	0.019	35	1.320	33.8	41.6	0.447	0.549
2	1.014	2.3	2.8	0.023	0.028	36	1.332	35.1	43.0	0.468	0.573
3	1.022	3.1	3.8	0.032	0.039	37	1.345	36.2	44.4	0.487	0.597
4	1.029	3.9	4.8	0.040	0.049	38	1.357	37.2	45.5	0.505	0.617
5	1.037	4.7	5.8	0.049	0.060	39	1.370	38.3	46.9	0.525	0.642
6	1.045	5.6	6.8	0.059	0.071	40	1.383	39.5	48.3	0.546	0.668
7	1.052	6.4	6.8	0.067	0.082	41	1.397	40.7	49.8	0.569	0.696
8	1.060	7.2	8.8	0.076	0.093	42	1.410	41.8	51.2	0.589	0.722
9	1.067	8.0	9.8	0.085	0.105	43	1.424	42.9	52.8	0.611	0.749
10	1.075	8.8	10.8	0.095	0.116	44	1.438	44.1	54.0	0.634	0.777
11	1.083	9.7	11.9	0.105	0.129	45	1.453	45.2	55.4	0.657	0.805
12	1.091	10.6	13.0	0.116	0.142	46	1.468	46.4	56.9	0.681	0.835
13	1.100	11.5	14.1	0.126	0.155	47	1.483	47.6	58.3	0.706	0.864
14	1.108	12.4	15.2	0.137	0.168	48	1.498	48.7	59.6	0.730	0.893
15	1.116	13.2	16.2	0.147	0.181	49	1.514	49.8	61.0	0.754	0.923
16	1.125	14.1	17.3	0.159	0.195	50	1.530	51.0	62.5	0.780	0.956
17	1.134	15.1	18.5	0.172	0.210	51	1.540	52.2	64.0	0.807	0.990
18	1.142	16.0	19.6	0.183	0.224	52	1.563	53.5	65.5	0.836	1.024
19	1.152	17.0	20.8	0.196	0.233	53	1.580	54.9	67.0	0.867	1.059
20	1.162	18.0	22.2	0.209	0.258	54	1.597	56.0	68.6	0.894	1.095
21	1.171	19.0	23.3	0.222	0.273	55	1.615	57.1	70.0	0.922	1.131
22	1.180	20.0	24.5	0.236	0.289	56	1.634	58.4	71.6	0.954	1.170
23	1.190	21.1	25.8	0.251	0.307	57	1.652	59.7	73.2	0.986	1.210
24	1.200	22.1	27.1	0.265	0.325	58	1.672	61.0	74.7	1.019	1.248
25	1.210	23.2	28.4	0.281	0.344	59	1.691	62.4	76.4	1.055	1.292
26	1.220	24.2	29.6	0.295	0.361	60	1.711	63.8	78.1	1.092	1.336
27	1.231	25.3	31.0	0.311	0.382	61	1.732	65.2	79.0	1.129	1.384
28	1.241	26.3	32.2	0.326	0.400	62	1.753	66.7	81.7	1.169	1.432
29	1.252	27.3	33.4	0.342	0.418	63	1.774	68.7	84.1	1.210	1.492
30	1.263	28.3	34.7	0.357	0.438	64	1.796	70.6	86.5	1.268	1.554
31	1.274	29.4	36.0	0.374	0.459	65	1.819	73.2	89.7	1.332	1.632
32	1.285	30.5	37.4	0.392	0.481	66	1.842	81.6	100.0	1.503	1.842
33	1.297	31.7	38.8	0.411	0.503						

*Table of the specific gravity and content of nitric acid,  
according to Kolb.*

Degrees, Baumé.	Specific gravity.	100 parts con- tain at 32° F.		100 parts con- tain at 59° F.		Degrees, Baumé.	Specific gravity.	100 parts con- tain at 32° F.		100 parts con- tain at 59° F.	
		HNO <sub>3</sub> .	N <sub>2</sub> O <sub>5</sub> .	HNO <sub>3</sub> .	N <sub>2</sub> O <sub>5</sub> .			HNO <sub>3</sub> .	N <sub>2</sub> O <sub>5</sub> .	HNO <sub>3</sub> .	N <sub>2</sub> O <sub>5</sub> .
0	1.000	0.0	0.0	0.2	0.1	28	1.242	36.2	31.0	38.6	33.1
1	1.007	1.1	0.9	1.5	1.3	29	1.252	37.7	32.3	40.2	34.5
2	1.014	2.2	1.9	2.6	2.2	30	1.261	39.1	33.5	41.5	35.6
3	1.022	3.4	2.9	4.0	3.4	31	1.275	41.1	35.2	43.5	37.3
4	1.029	4.5	3.9	5.1	4.4	32	1.286	42.6	36.5	45.0	38.6
5	1.036	5.5	4.7	6.3	5.4	33	1.298	44.4	38.0	47.1	40.4
6	1.044	6.7	5.7	7.6	6.5	34	1.309	46.1	39.5	48.6	41.7
7	1.052	8.0	6.9	9.0	7.7	35	1.321	48.0	41.1	50.7	43.5
8	1.060	9.2	7.9	10.2	8.7	36	1.334	50.0	42.9	52.9	45.3
9	1.067	10.2	8.7	11.4	9.8	37	1.346	51.9	44.5	55.0	47.1
10	1.075	11.4	9.8	12.7	10.9	38	1.359	54.0	46.3	57.3	49.1
11	1.083	12.6	10.8	14.0	12.0	39	1.372	56.2	48.2	59.6	51.1
12	1.091	13.8	11.8	15.3	13.1	40	1.384	58.4	50.0	61.7	52.9
13	1.100	15.2	13.0	16.8	14.4	41	1.398	60.8	52.1	64.5	55.3
14	1.108	16.4	14.0	18.0	15.4	42	1.412	63.2	54.2	67.5	57.9
15	1.116	17.6	15.1	19.4	16.6	43	1.426	66.2	56.7	70.6	60.5
16	1.125	18.9	16.2	20.8	17.8	44	1.440	69.0	59.1	74.4	63.8
17	1.134	20.2	17.3	22.2	19.0	45	1.454	72.2	61.9	78.4	67.2
18	1.143	21.6	18.5	23.6	20.2	46	1.470	76.1	65.2	83.0	71.1
19	1.152	22.9	19.6	24.9	21.3	47	1.485	80.2	68.7	87.1	74.7
20	1.161	24.2	20.7	26.3	22.5	48	1.501	84.5	72.4	92.6	79.4
21	1.171	25.7	22.0	27.8	23.8	49	1.516	88.4	75.8	96.0	82.3
22	1.180	27.0	23.1	29.2	25.0	49.5	1.524	90.5	77.6	98.0	84.6
23	1.190	28.5	24.4	30.7	26.3	49.9	1.530	92.2	79.0	100.0	85.7
24	1.199	29.8	25.5	32.1	27.5	50.0	1.532	92.7	79.5	—	—
25	1.210	31.4	26.9	33.8	28.9	50.5	1.541	95.0	81.4	—	—
26	1.221	33.1	28.4	35.5	30.4	51.0	1.549	97.3	83.4	—	—
27	1.231	34.6	29.7	37.0	31.7	51.5	1.559	100.0	85.7	—	—

*Table showing the specific gravity of sal ammoniac solutions at  
66.2 F., according to Schiff.*

Content of the solution, per cent.	Specific gravity.	Content of the solution, per cent.	Specific gravity.	Content of the solution, per cent.	Specific gravity.
1	1.0029	11	1.0322	21	1.0606
2	1.0058	12	1.0351	22	1.0633
3	1.0087	13	1.0380	23	1.0660
4	1.0116	14	1.0409	24	1.0687
5	1.0145	15	1.0438	25	1.0714
6	1.0174	16	1.0467	26	1.0741
7	1.0203	17	1.0495	27	1.0768
8	1.0233	18	1.0523	28	1.0794
9	1.0263	19	1.0551	29	1.0820
10	1.0293	20	1.0579	30	1.0846

*Table showing the electrical resistance of pure copper wire of various diameters.*

No. of wire, Birmingham wire gauge.	Resistance of 1 foot in ohms.	Number of feet required to give resistance of 1 ohm.	No. of wire, Birmingham wire gauge.	Resistance of 1 foot in ohms.	Number of feet required to give resistance of 1 ohm.
0000	0.0000516	1935.8	17	0.00316	316.1
000	0.0000589	1696.4	18	0.00443	225.5
00	0.0000737	1356.2	19	0.00603	165.7
0	0.0000922	1085.7	20	0.00869	115.1
1	0.000118	8452.6	21	0.01040	96.2
2	0.000132	7575.1	22	0.01358	73.6
3	0.000159	6300.1	23	0.01703	58.7
4	0.000188	5319.9	24	0.02200	45.5
5	0.000220	4545.9	25	0.02661	37.6
6	0.000258	3870.3	26	0.03286	30.4
7	0.000329	3043.4	27	0.04159	24.0
8	0.000391	2557.1	28	0.05432	18.4
9	0.000486	2057.7	29	0.06300	15.9
10	0.000593	1686.5	30	0.07393	13.5
11	0.000739	1352.5	31	0.10646	9.4
12	0.000896	1116.0	32	0.13144	7.6
13	0.001180	847.7	33	0.16634	6.0
14	0.001546	647.0	34	0.21727	4.6
15	0.002053	487.0	35	0.42583	2.4
16	0.002520	396.8	36	0.66537	1.5

*Resistance and conductivity of pure copper at different temperatures.*

Centigrade temperature.	Resistance.	Conductivity.	Centigrade temperature.	Resistance.	Conductivity.
0°	1.00000	1.00000	16°	1.06168	.94190
1	1.00381	.99624	17	1.06563	.93841
2	1.00756	.99250	18	1.06959	.93494
3	1.01135	.98878	19	1.07356	.93148
4	1.01515	.98508	20	1.07742	.92814
5	1.01896	.98139	21	1.08164	.92452
6	1.02280	.97771	22	1.08553	.92121
7	1.02663	.97406	23	1.08954	.91782
8	1.03048	.97042	24	1.09365	.91445
9	1.03435	.96679	25	1.09763	.91110
10	1.03822	.96319	26	1.10161	.90776
11	1.04199	.95970	27	1.10567	.90443
12	1.04599	.95603	28	1.111972	.90113
13	1.04990	.95247	29	1.11382	.89784
14	1.05406	.94893	30	1.11782	.89457
15	1.05774	.94541			

*Table showing actual diameters in decimal parts of an inch corresponding to the numbers of various wire gauges.*

No. of wire gauge.	Roebbling.	Brown & Sharpe.	Birmingham or Stubs.	English legal standard.	Old English or London.
000000	.46	—	—	.464	—
00000	.43	—	—	.432	—
0000	.393	.46	.454	.4	.454
000	.362	.40964	.425	.372	.425
00	.331	.3648	.380	.348	.38
0	.307	.32495	.340	.324	.34
1	.283	.2893	.3	.3	.3
2	.263	.25763	.284	.276	.284
3	.244	.22942	.259	.252	.259
4	.225	.20431	.238	.232	.238
5	.207	.18194	.22	.212	.22
6	.192	.16202	.203	.192	.203
7	.177	.14428	.18	.176	.18
8	.162	.12849	.165	.16	.165
9	.148	.11443	.148	.144	.148
10	.135	.10189	.134	.128	.134
11	.120	.09074	.12	.116	.12
12	.105	.08081	.109	.104	.109
13	.092	.07196	.095	.092	.095
14	.08	.06408	.083	.08	.083
15	.072	.05706	.072	.072	.072
16	.063	.05082	.065	.064	.065
17	.054	.04525	.058	.056	.058
18	.047	.0403	.049	.048	.049
19	.041	.03589	.042	.04	.04
20	.035	.03196	.035	.036	.035
21	.032	.02846	.032	.032	.0315
22	.028	.02534	.028	.028	.0295
23	.025	.02257	.025	.024	.027
24	.023	.0201	.022	.022	.025
25	.02	.0179	.02	.02	.023
26	.018	.01594	.018	.018	.0205
27	.017	.01419	.016	.0164	.01875
28	.016	.01264	.014	.0148	.0165
29	.015	.01125	.013	.0136	.0155
30	.014	.01002	.012	.0124	.01375
31	.0135	.00893	.010	.0116	.01225
32	.013	.00795	.009	.0108	.01125
33	.011	.00708	.008	.01	.01025
34	.01	.0063	.007	.0092	.0095
35	.0095	.00561	.005	.0084	.009
36	.009	.005	.004	.0076	.0075



*Weight of iron, copper, and brass wire and plates.*

(Diameters and thickness determined by American gauge.)

No. of gauge.	Size of each No.	WEIGHT OF WIRE PER 1000 LINEAL FEET.				WEIGHT OF PLATES PER SQUARE FOOT.			
		Wro't iron.	Steel.	Copper.	Brass.	Wro't iron.	Steel.	Copper.	Brass.
	<i>Inch.</i>	<i>Lbs.</i>	<i>Lbs.</i>	<i>Lbs.</i>	<i>Lbs.</i>	<i>Lbs.</i>	<i>Lbs.</i>	<i>Lbs.</i>	<i>Lbs.</i>
oooo	.46000	560.74	566.03	640.51	605.18	17.25	17.48	20.838	19.688
ooo	.40964	444.68	448.88	507.95	479.91	15.3615	15.5663	18.557	17.533
oo	.36480	352.66	355.99	402.83	380.67	13.68	13.8624	16.525	15.613
o	.32486	279.67	282.30	319.45	301.82	12.1823	12.3447	14.716	13.904
1	.28930	221.79	223.89	253.34	239.35	10.8488	10.9034	13.105	12.382
2	.25763	175.89	177.55	200.91	189.82	9.6611	9.7809	11.671	11.027
3	.22942	139.48	140.80	159.32	150.52	8.6033	8.7180	10.393	9.8192
4	.20431	110.62	111.65	126.35	119.38	7.6616	7.7638	9.2552	8.7445
5	.18194	87.720	88.548	100.20	94.666	6.8228	6.9137	8.2419	7.787
6	.16202	69.565	70.221	79.462	75.075	6.0758	6.1568	7.3395	6.9345
7	.14428	55.165	55.685	63.013	59.545	5.4105	5.4826	6.5359	6.1752
8	.12849	43.751	44.164	49.976	47.219	4.8184	4.8826	5.8206	5.4994
9	.11443	34.699	35.026	39.636	37.437	4.2911	4.3483	5.1837	4.8976
10	.10189	27.512	27.772	31.426	29.687	3.8209	3.8718	4.6156	4.3609
11	.090742	21.820	22.026	24.924	23.540	3.4028	3.4482	4.1106	3.8838
12	.080868	17.304	17.468	19.766	18.676	3.0303	3.0707	3.6666	3.4586
13	.071961	13.722	13.851	15.674	14.809	2.6985	2.7345	3.2598	3.0799
14	.064684	10.886	10.989	12.435	11.746	2.4032	2.4382	2.9030	2.7428
15	.057668	8.631	8.712	9.859	9.315	2.1401	2.1686	2.5852	2.4425
16	.050820	6.845	6.909	7.819	7.587	1.9058	1.9312	2.3021	2.1751
17	.045257	5.427	5.478	6.199	5.857	1.6971	1.7198	2.0501	1.937
18	.040303	4.304	4.344	4.916	4.645	1.5114	1.5315	1.8257	1.725
19	.025890	3.413	3.445	3.899	3.684	1.3459	1.3638	1.6258	1.5361
20	.031961	2.708	2.734	3.094	2.920	1.1985	1.2145	1.4478	1.3679
21	.028462	2.147	2.167	2.452	2.317	1.0673	1.0816	1.2893	1.2182
22	.025347	1.703	1.719	1.945	1.838	.95051	.96319	1.1482	1.0849
23	.022571	1.350	1.363	1.542	1.457	.84641	.8577	1.0225	.96604
24	.020100	1.071	1.081	1.223	1.155	.75375	.7638	.91053	.86028
25	.017900	0.8491	0.8571	.9699	.9163	.67125	.6822	.81087	.76612
26	.015941	0.6734	0.6797	.7692	.7267	.59775	.60572	.72208	.68223
27	.014195	0.5340	0.5391	.6099	.5763	.53231	.53941	.64303	.60755
28	.012641	0.4235	0.4275	.4837	.4570	.47404	.48036	.57264	.54103
29	.011257	0.3358	0.3380	.3835	.3624	.42214	.42777	.50994	.48180
30	.010025	0.2663	0.2688	.3042	.2874	.37594	.38092	.45413	.42907
31	.008928	0.2113	0.2132	.2413	.2280	.3348	.33926	.40444	.38212
32	.007950	0.1675	0.1691	.1913	.1808	.28813	.2921	.36014	.34026
33	.007080	0.1328	0.1341	.1517	.1434	.2655	.26904	.32072	.30302
34	.006304	0.1053	0.1063	.1204	.1137	.2364	.23955	.28557	.26981
35	.005614	0.08366	0.08445	.0956	.0915	.21053	.21333	.25431	.24028
36	.005000	.06625	.06687	.0757	.0715	.1875	.19	.2265	.2140
37	.004453	.05255	.05304	.06003	.05671	.16699	.16921	.20172	.19059
38	.003905	.04166	.04205	.04758	.04496	.14869	.15067	.17961	.16973
39	.003531	.03305	.03336	.03755	.03566	.13241	.13418	.15995	.1511
40	.003144	.02620	.02644	.02992	.02827	.1179	.11947	.14242	.13456
Specific grav. ....		7.7747	7.847	8.880	8.326	7.200	7.096	8.698	8.218
Weight per cubic foot. ....		185.874	90.45	554.988	524.16	450.	456.	543.6	513.6

*Rules for Speed.*

*To find speed of counter-shaft in accordance with main shaft and machine.*—Subtract the number of revolutions on the main shaft from the number of revolutions the machine should make ; divide the remainder by two. The quotient will show the number of revolutions of the counter-shaft.

*Example.*—The main shaft runs 200 revolutions per minute, while the machine should run 1000 revolutions per minute. Deduct 200 from 1000, leaving 800, which divide by 2 ; the quotient will then be 400, which is the number of revolutions the counter-shaft should make.

*To find diameter of pulley on the main shaft.*—Multiply the diameter in inches of the receiving pulley of the counter-shaft by the number of revolutions the counter-shaft should make and divide the product by the number of revolutions the main shaft makes.

*Example.*—The counter-shaft makes 400 revolutions, the receiving pulley is  $7\frac{1}{2}$  inches in diameter, and the main shaft makes 200 revolutions ; 400 times  $7\frac{1}{2}$  equals 3000, which divided by 200 equals 15 ; this is the diameter in inches of the pulley on the main shaft.

*To find diameter of pulley on counter-shaft carrying belt to machine.*—Multiply the number of revolutions the machine should make by the diameter of pulley of the machine, and divide by the number of revolutions the counter-shaft makes.

*Example.*—Say the machine should make 1000 revolutions, the diameter of pulley on machine being 6 inches, and the counter-shaft making 400 revolutions ; then multiplying 1000 by 6 equals 6000 ; dividing this by 400 gives 15, which should be the diameter of the pulley carrying belt from counter-shaft to machine.

*To find the speed of a machine.*—Multiply the number of revolutions of the main shaft by the diameter of pulley in inches, and divide by the diameter of receiving pulley of the counter-shaft. The result is the speed of the counter-shaft.

Then multiply the number of revolutions of counter-shaft by diameter of transmitting pulley, and divide by diameter of pulley on machine. The result will be the speed of the machine. It should be well understood that no other pulleys but those in contact with one belt should be considered.

*Comparison of the Scales of the Fahrenheit, Centigrade, and Réaumur Thermometers, and Rules for Converting one Scale into another.*

These three thermometers are graduated so that the range of temperature between the freezing and boiling points of water is divided by Fahrenheit's scale into 180 (from  $32^{\circ}$  to  $212^{\circ}$ ), by the Centigrade into 100 (from  $0^{\circ}$  to  $100^{\circ}$ ), and by that of Réaumur into 80 (from  $0^{\circ}$  to  $80^{\circ}$ ) portions or degrees.

The spaces occupied by a degree of each scale are consequently as  $\frac{1}{9}$ ,  $\frac{1}{5}$ , and  $\frac{1}{4}$  respectively, or as 1, 1.8, and 2.25; and the number of degrees denoting the same temperature, by the three scales, when reduced to a common point of departure by subtracting 32 from Fahrenheit's, are as 9, 5, and 4. Hence, we derive the following equivalents:—

A degree of Fahrenheit's is equal to 0.5 of the Centigrade or to 0.4 of Réaumur's; a degree of Centigrade is equal to 1.8 of Fahrenheit's or to 0.8 of Réaumur's; and a degree of Réaumur's is equal to 2.25 of Fahrenheit's, or to 1.25 of the Centigrade.

To convert degrees of Fahrenheit into the Centigrade or Réaumur's, subtract 32 and multiply the remainder by  $\frac{5}{9}$  for the Centigrade or  $\frac{4}{9}$  for Réaumur's.

To convert degrees of the Centigrade or Réaumur's into Fahrenheit's, multiply the Centigrade by  $\frac{9}{5}$ , or Réaumur's by  $\frac{9}{4}$ , as the case may be, and add 32 to the product.

## INDEX.

- A**CCUMULATOR, common form  
of, 91  
plant, installed by Electro-  
Chemical Storage Battery  
Co., 91, 92
- Accumulators, 87-92  
capacity of, 89  
chemical processes which take  
place in, 89  
galvano-plastic deposition with,  
438, 439
- Acid copper baths, examination of,  
425-427  
free, determination of, in the acid  
copper bath, 425  
potassium carbonate, 507  
regaining of, from exhausted  
dipping baths, 168, 169
- Acids, determination of, in nickel  
baths 249, 250  
organic, salts of, 516, 517  
used in electro-plating, 493-497
- Alexander's process of zincking, 391
- Alkalies and alkaline earths, 497, 498  
poisoning by, 491
- Alkaline platinate bath, 377
- Alliance machine, 7, 8
- Alloys, metallic, first deposition of, 6  
for moulds, 452  
table of, 529
- Alternating current machines, 69  
currents, 25
- Aluminium baths; 408, 409  
deposition of, 407-411  
electro-deposition upon, 409-411  
properties of, 407, 408
- Amalgam of gold, preparation of, 367
- Amalgamating, 309
- Amalgamation of the zinc, 36, 37
- Ammeter, Weston, 121, 122
- Ammeters, 118-123
- Ammonia, 497, 498
- Ammonium alum, 510  
chloride, 500  
hydrate, 497, 498  
phosphate, 515  
potassium sulphate, 509, 510  
sulphate, 509
- Ampère's theory of magnetism, 11, 12
- Ampère, the, 34  
hours, 89
- Analysis, electrolytic, 253-255  
gravimetric, 251, 252  
volumetric, 252, 253
- Anions, 26, 28
- Anode, 26  
wire, 109  
main and main object wire,  
coupling of the, with the  
resistance boards, volt-  
meter, switch and baths,  
123, 124
- Anodes, arrangement of, 112-114  
carbon, use of, in gold-plating,  
348  
choice of, 182, 183  
for brassing, 287  
copper plating, 268  
galvanoplastic baths, 424, 425  
insoluble, 199  
platinum, 299, 300  
mode of suspending the, 113, 114  
nickel, 198-202  
platinum, use of, in gold-plating,  
348  
silver, 298  
steel, use of, in gold-plating, 346-  
348  
unequal wear of, 177
- Antimony and arsenic, deposits of,  
by contact and immersion, 407  
arsenic, aluminium, deposition  
of, 404-411  
baths, 404, 405  
deposition of, 404, 405  
potassium tartrate, 516  
properties of, 404  
sulphide, 499  
trichloride, 500
- Antique silvering, 331, 332
- Apparatus and instruments, various,  
517-522
- Aqua fortis, 494
- Arcas silver-plating, 306-308
- Argentiferous pastes, 326
- Argol, 516



- Armature, 67  
 drum, Hefner-Altenbeck's, 74  
 Gramme, 70
- Arsenic, 496  
 and antimony, deposits of, by  
 contact and immersion, 407  
 baths, 406  
 deposition of, 405-407  
 deposits, defective, cause of, 407  
 poisoning by, 491  
 properties of, 405, 406  
 trisulphide, 499, 500
- Arsenious acid, 496  
 addition of, to brass  
 baths, 282  
 chloride, 501  
 sulphide, 499, 500
- Astatic galvanometer, 22
- Atoms, 26
- Auric chloride, 503
- Australian patent for directly silver-  
 plating iron and steel, 316
- B**ACCO'S copper bath, 273  
 Backing metal, 442  
 Backing the deposit or shell, 440-442  
 Baking powder, 508  
 Balance, plating, 312-314  
 Balloons, glass, 517  
 Barium cyanide, determination of  
 quantity of, 336  
 Baskets, dipping, 212, 213  
 Bath, bright-dipping, 163, 164  
 electro-plating, requisites of a,  
 184  
 for galvanoplasty in gold, 467  
 silver, 467  
 lasting qualities of the, 182
- Baths, agitation of, 177, 178  
 aluminium, 408, 409  
 antimony, 404, 405  
 arsenic, 406  
 boiling of, 181  
 boric acid as an addition to, 188,  
 189  
 brass, 281-286  
 bronze, 292, 293  
 cobalt, 256, 257  
 concentration of, 175  
 copper, 261-267  
 copper, for galvano-plastic depo-  
 sitions with a separate source  
 of current, 420, 421  
 estimation of the condition of, by  
 the hydrometer, 175, 176  
 for galvanoplasty in iron, 464  
 silvering by immersion, 320,  
 321
- Baths, gold, 341-346  
 heating of, 94, 95  
 iron, 400-402  
 lead, 397  
 nickel, 187-198  
 palladium, 382  
 platinum, 375-379  
 purity of the chemicals for the,  
 174  
 steel, 400-402  
 stirring up the, 176  
 suspension of objects in the, 204,  
 205  
 temperature of, 180, 181  
 tin, 383-386  
 vats for heating, 112
- Batteries, bichromate, 56  
 plunge, 56
- Battery, Cruikshank's trough, 2, 3  
 Foote's pinnacle gravity, 46, 47  
 galvanoplastic depositions with  
 the, 419, 420  
 trough, 35
- Baumé hydrometer, 519
- Beardslee, G. W., cobalt solution re-  
 commended by, 258
- Beeswax, moulding in, 431
- Bell metal, 280
- Belt strapping attachment or endless  
 belt machine, 153, 154
- Benzine, removal of grease with, 170,  
 171
- Bertrand's aluminium bath, 408  
 palladium bath, 382
- Bicarbonate of potash, 507  
 of soda, 508
- Bichromate batteries, 56  
 battery, Fein's, 56, 57  
 Keiser and Schmidt's, 57  
 element, 58
- Bicycle spokes, plating apparatus for,  
 216, 217
- Binding posts and screws, 113
- Bird, production of the amalgams of  
 potassium and sodium by, 4
- Bisulphide of carbon, 499  
 addition of, to nickel  
 baths,  
 196  
 to silver  
 baths,  
 304, 305
- Bivalent anions, 28  
 kations, 28
- Black color, lustrous, on iron, 482  
 upon copper, 471, 472  
 -lead, gilt or silvered, 434  
 -leading machines, 432, 433

- Black-leading moulds, 431-434  
     wet method of, 433, 434  
     lustrous, on brass, 474, 475  
     sulphide of antimony, 499
- Blue-black color on copper, 471  
     color on iron, 483  
         steel, 483  
     copperas, 510, 511  
     -gray color on copper, 471  
     vitriol, 510, 511  
         table of approximate content  
         of, in solutions at different  
         degrees Bé, 417, 418
- Bobs, cloth, 149  
     construction of, 222, 223  
     polishing, 148, 149
- Boiling pans, 181
- Boric acid as an addition to baths, 188,  
     189  
     determination of, 250  
     or boracic acid, 495, 496
- Bossard mechano-electroplating  
     tanks, 178-180
- Böttger on the deposition of nickel  
     from its double salt, 6
- Böttger's iron bath, 400  
     platinum bath, 375  
     tinning solution, 388
- Bouant's method of amalgamation, 37
- Brass and bronzes, coloring of, 474-  
     479  
     articles, cobalt bath for, 258, 259  
     en masse, brown color on, 477  
     silvered, spurious gilding of,  
         478  
     small, tinning solution for,  
         388  
     baths, 281-286  
         examination of, 290  
     bronze, Barbédienne on, 476  
     brown color on, 476  
     castings, grinding of, 148  
     cleansing of, 171  
     coating of, with a bright layer of  
         zinc, 395  
     color resembling gold on, 475, 476  
     coloring, Ebermayer's experi-  
         ments in, 478, 479  
     corn-flower blue on, 477, 478  
     dark red brown color on, 477  
     deposition of, 280-292  
     deposits, polishing of, 160  
     gray color with a bluish tinge on,  
         475  
     lustrous black on, 474, 475  
         colors on, 478  
     nickel bath for, 195  
     nickeling of, 203
- Brass, niel upon, 331  
     pale gold color on, 475  
     pickling of, 163  
     potassium cyanide as a pickle for,  
         164  
     preparation of, for silver-plating,  
         308, 309  
     scratch-brushing of, 157  
     sheets, nickeling of, 236, 237  
         treatment of, 148  
     steel-gray on, 475  
     straw color to brown, through  
         golden-yellow and tombac  
         color on, 475  
     varieties of, 280  
     various colors upon, 473, 474  
     violet color on, 477, 478  
     wire and plates, table of weight  
         of, 536
- Brassed iron, brown-black color on,  
     476  
     zinc, brown-black color on, 476
- Brassing, anodes used for, 287  
     by contact and dipping, 289  
     distance of the objects from the  
         anodes in, 289  
     execution of, 286-289  
     small articles, bath for, 285, 286
- Bright dipping bath, 163, 164  
     plating, preparations for silver  
         baths, 304, 305  
     Platinum Plating Co., platinum  
         bath patented by, 375
- Britannia, cleansing of, 171  
     nickeling of, 203  
     ware, preparation of, for plating,  
         318  
         silver-plating of, 316, 317
- Bronze articles, clay-yellow color on,  
     476, 477  
     dark brown color on, 476,  
         477  
     dead-yellow color on, 476,  
         477
- Bronze Barbédienne on brass, 476  
     baths, 292, 293  
     cleansing of, 171  
     deposition of, 292, 293  
     pickling of, 163
- Bronzes, 280  
     and brass, coloring of, 474-479
- Bronzing, execution of, 293  
     on zinc, 481
- Brown-black color on brass, 476  
     zinc, 476  
     color, dark, on bronze articles,  
         476, 477  
     upon brass, 476

- Brown color upon articles en masse, 477  
     copper, 470, 471  
 Brugnatelli, first practical results in electro-gilding attained by, 3  
 Brush-coppering, 273  
 Brushes, 136  
     management of the, 116  
 Buffing, flexible shafts for, 154, 155  
 Bunsen element, 40-46  
     location of, 43, 44  
     elements, manipulation of, 45, 46  
     plunge battery, 56  
 Burnishers, 160, 161  
 Burnishing, 156, 160, 161  
     machines, 315  
 Burnt lime, 498  
 Busts, galvanoplastic reproduction of, 449-455  
     moulding of, 450, 451  
 Butter of antimony, 500  
     zinc, 501
- C**ALCIUM carbonate, 508  
     hydrate, 498  
 Capsules, evaporating, 517, 518  
 Carbon, anodes, use of, in gold-plating, 348  
     artificial, 40, 41  
     bisulphide of, addition of, to  
         nickel baths, 196  
         addition of, to  
         silver baths, 304, 305  
     disulphide or bisulphide, 499  
     gas, 41, 42  
 Carbonates, 507-509  
 Carboy rocker, steel spring, 172  
 Cast iron articles, pickling of, 162  
     bath for brassing, 284, 285  
         zincking, 392  
     solution for coating with  
         bronze, 292  
     tin bath for, 384  
 Casting and melting table, 439, 440  
 Cathode, 26  
 Caustic potash, 497  
     soda, 497  
 Cell-apparatus, 414-416  
     copper bath for, 417  
     French form of, 416, 417  
     galvanoplastic deposition in the, 413-418  
     German form of, 417  
     large, 416, 417  
 Cellulose lacquers and varnishes, 487, 488
- Centigrade, Réaumur and Fahrenheit thermometers, comparison of the scales of, and rules for converting one scale into another, 538  
 Chain, galvanic, 16  
 Chains, plating apparatus for, 216  
 Chalk, 508  
 Chemical action of the electric current, 25-33  
     and electro-chemical equivalents, table of, 524, 525  
     products, 493-517  
     and various apparatus and instruments used in electro-plating, 493-522  
     treatment of metallic articles, 161-172  
 Chemicals for the baths, purity of, 174  
 Chile saltpetre, 514  
 Chloride of zinc, qualities of, 174  
 Chlorine combinations, 500-504  
     poisoning by, 492  
 Chromic acid, 496  
 Chromium combination for Bunsen cells, 44, 45  
 Circuit, closed, 16  
 Circular scratch brush, construction of a, 135, 136  
 Citric acid, 495  
     determination of, 250  
 Clamond's thermo-electric pile, 61, 62  
 Clausius's theory of the molecules, 26, 27  
 Clay, metallization of, 463  
 Clichés, nickeling of, 242-244  
 Clock cases of iron and steel, dead black coating on, 483  
 Closed circuit, 16  
 Cloth bobs, 149  
 Cobalt bath, Daub's, 258, 259  
 Cobalt baths, 256, 257  
     carbonate, 509  
     chloride, 502  
     deposition of, 256-260  
     properties of, 256  
     solution, Beardslee's, 258  
         Warren's, 258  
     sulphate, 513  
 Cobalting by contact, 259, 260  
 Coins, dies for, production of, 448, 449  
 Colcothar, 155  
 Cold gilding, baths for, 342-344  
 Collecting brushes, 67  
 Collector, 67  
 Coloring of brass and bronzes, 474-479

- Coloring of copper, 469-474  
     iron, 481-484  
     tin, 484  
     zinc, 479-481  
     patinizing, oxidizing, etc., of  
         metals, 469-488  
 Colors, iridescent, 4, 397-399  
 Common salt, 500  
 Commutator, 67  
     cylinder, 67  
     management of the, 116  
 Conducting power of metals, 17  
     salts, 187, 188  
     wires, calculating the thickness  
         of, for dynamos, 129, 131  
         insulation of, 109  
 Conductors, bad, 13  
     good, 13  
 Constant elements, 38  
 Contact electricity, discovery of, 1  
 Continuous current machines, 69  
 Copper acetate, 516, 517  
     alloys, silvering articles of, 323-  
         325  
     articles, cobalt bath for, 258, 259  
         gilded, stripping of, 371  
         scouring and pickling of, 269  
         silvered, stripping of, 333  
         small, tinning solution for,  
             388  
     bath for the cell-apparatus, 417  
         removal of excess of acid  
         from, 418  
     baths, 261-267  
         acid, examination of, 425-  
             427  
         containing potassium cya-  
         nide, examination of, 274-  
             280  
         for galvanoplastic depositions  
         with a separate source of  
         current, 420, 421  
         galvanoplastic, contrivances  
         for the agitation of, 423,  
             424  
         without potassium cyanide,  
             266  
         wooden vats lined with lead  
         for, 110, 111  
     black color on, 471  
     blue-back color on, 471  
     blue-gray color on, 471  
     brass and bronze, deposition of,  
         261-293  
     brown color upon, 470, 471  
     carbonate, 508  
     castings, grinding of, 148  
     chemically pure, 412  
 Copper chloride, 501  
     cleansing of, 171  
     coating of, with a bright layer of  
         zinc, 395  
     coloring of, 469-474  
     current density for nickeling, 206  
     cyanides, 505, 506  
     deposit of, upon porcelain, pot-  
         tery, stoneware, etc., 463  
     deposition of, 261-280  
     deposits, polishing of, 160, 270, 271  
     determination of quantity of, dis-  
         solved in stripping cobalted  
         copper plates, 257, 258  
     electrolytic determination of, in  
         the acid copper bath, 426, 427  
     in brass baths, determination of,  
         290  
     in copper baths, determination of,  
         by electrolysis, 277;  
             278  
         volumetric determin-  
         ation of, 278-280  
     matt-black on, 471, 472  
     nickel bath for, 195  
     nickeling of, 203  
     pickling of, 163  
     plates, cobalting of, 257, 258  
     -plating, anodes used in, 268  
         execution of, 267-272  
         prevention of the formation  
         of stains in, 270  
     preparation of, for silver-plating,  
         308, 309  
     printing plates, galvanoplastic  
         bath for, 421  
         steeling of, 400, 401  
     properties of, 261  
     pure, table of resistance and con-  
         ductivity of, 534  
     red-brown color on, 471  
     reduction of, from its solution by  
         iron, early knowledge of, 1  
     salts, poisoning by, 491  
     scratch-brushing of, 157  
     sheet, treatment of, 148  
     sheets, nickeling of, 236, 237  
     silvering of, early knowledge of, 1  
     steel-gray color upon, 473  
     sulphate, 510, 511  
         solutions, table of specific  
         electrical resistances of, 526  
     sulphite, baths with, 265  
     tubes, production of, by galvano-  
         plastic deposition, 460, 461  
     various colors upon, 473, 474  
     volumetric determination of, in  
         the acid copper bath, 425, 426



- Copper wire and plates, table of  
weight of, 536  
fine, silvering of, 329  
pure, table of electrical  
resistance of, 534  
-zinc alloy, solutions for transfer-  
ring any, 285
- Copperas, 510  
blue, 510, 511
- Coppered art-castings, inlaying of,  
274  
articles, coating of, with another  
metal, 271
- Coppering by contact and dipping,  
272, 273  
small articles en masse, 272
- Cork wheels, 143
- Corn-flower blue on brass, 477, 478
- Corvin's niello, 461
- Coulomb, the, 34
- Coulomb's law, 15
- Counter-current, 27, 210, 211  
shaft, to find speed of, in accord-  
ance with main shaft, 537
- Cream of tartar, 516
- Crucibles, 518
- Cruikshank's investigations, 3  
trough battery, 2, 3
- Cubic nitre, 514
- Cuivre fumé, 471
- Cupric cyanide, 505, 506  
sulphate, 510, 511
- Cupron, copper bath with, 265  
element, 53, 54
- Cuprous cyanide, 505, 506  
sulphite, 511
- Cups, gilding of, 352
- Current-carrying wire, size of, 108  
counter, 27, 210, 211  
density for silvering, 100  
electric, chemical action of, 25-33  
galvanic, 16  
hydro electric, 16  
induced, 24  
inductive, 24  
polarizing, 27, 210, 211  
formation of, 30  
primary, 24  
quantity of, 17-21  
coupling the elements  
for, 20  
regulator, 101-103  
secondary, 24  
services of, 35-92  
volumes, equal, table of value of,  
525, 526
- Currents, alternating, 25  
extra, 25
- Cutlery, preparation of, for plating,  
318
- Cyanides, 504-507  
poisoning by, 490, 491
- D**ANIELL element, 38, 39  
Daub's cobalt bath, 258, 259
- Davy, Sir H., discovery of the metals  
potassium and sodium by, 3
- Deposit, backing the, 440-442  
formation of the, 132, 133  
penetration of the, into the basis-  
metal, 183
- Deposition, galvanoplastic, by the  
battery and dyna-  
mo, 418-425  
in the cell appara-  
tus, 413-418
- of aluminium, 407-411  
antimony, 404, 405  
arsenic, aluminium, 404-  
411  
arsenic, 405-407  
brass, 280-292  
bronze, 292, 293  
cobalt, 256-260  
copper, 261-280  
brass and bronze, 261-293  
iridium, 382  
iron, 399-403  
gold, 339-374  
lead, 396-399  
nickel, 186-256  
and cobalt, 186-260  
palladium, 381, 382  
platinum, 375-381  
and palladium, 375-382  
rhodium, 382  
silver, 294-339  
tin, 383-390  
zinc, lead and iron, 383-403  
zinc, 390-396
- Deposits, polishing of, 160, 161
- De Ruolz, first deposition of metallic  
alloys by, 6
- Dies for coins, reliefs, etc., production  
of, 448, 449
- Dip-lacquers, 487, 488
- Dipping, 115  
and pickling, 162-164  
baskets, 212, 213  
baths, exhausted, regaining of  
acid and metal from, 168, 169
- Dishes, evaporating, 517, 518
- Doctor, the, 245
- Double fluid hypothesis of electricity,  
14
- Drinking cups, gilding of, 352

- Drum armature, Hefner-Altenbeck's, 74
- Du Fresne's method of gilding, 370, 371
- Dun's potash element, 54, 55
- Dupré's solution for Bunsen cells, 44
- Dynamo- and magneto-electric machines, 65-87
- data for ordering a, 87-92
- electric machine, definition of a, 67
- parts of a, 67
- electrical machines, American types, 9
- European types, 9
- Fein's, 73, 74
- first application of the term, 67
- for plating purposes, evolution of the, in the United States, 80-82
- galvanoplastic deposition with the, 420-425
- generator, parts of a, 67
- Gramme, 70, 71
- Kröttlinger's, 76, 77
- Hansen & Van Winkle Co.'s, 82-85
- Lahmeyer's, 77-79
- Langbein & Co.'s, 79, 80
- "Little Wonder," 81
- rheostat, location of, 118
- rules for setting up and running a, 115-117
- Schuckert's, 72, 73
- Weston, 81
- with auxiliary apparatus, scheme of a, 118
- "Wonder," 81, 82
- Dynamos, arrangement with, 115-131
- calculating the thickness of conducting wires for, 129, 131
- various constructions of, 86
- Dyne, 33
- E**BERMAYER'S experiments in
- coloring brass, 478, 479
- silver immersion bath, 323
- Elbs's theory of the accumulator, 89
- Electric connection gripper, 435
- current, chemical action of, 25-33
- currents, attraction and repulsion of, 23
- generators, classes of, 69
- induction, discovery of, 4
- potential, 16
- units, 33, 34
- Electricities, attraction and repulsion of, 13
- Electricity, 12-34
- Electricity and magnetism, 10-12
- double fluid hypothesis of, 14
- kinds of, 13
- single fluid hypothesis of, 14, 15
- Electro-chemical equivalents, 32, 33
- Storage Battery Co., accumulator plant installed by the, 91, 92
- chromy, 397-399
- deposition and fire-gilding, combination of, 369-371
- by contact, 184, 185
- first requisite for the result of the process of, 99, 100
- of iron, principal use of, 399
- processes of, 173-185
- depositions upon aluminium, 409-411
- etching, 445-447
- in steel for the production of dies for coins, reliefs, etc., 448, 449
- gilder's brush, 136
- gilding, first practical results in, 3
- magnet, 12
- magnetic induction machine, first, construction of, 4
- magnetism, 21-23
- magnets, 23
- metallurgy, historical review of, 1-9
- motive force, 16
- of elements, table of, 527
- or power, 33, 34
- or tension, coupling the elements for, 20
- series of, 15
- plated objects, finished, treatment of, 159-161
- plates, finishing the, 443, 444
- plating, additional rules for, 209, 210
- arrangements in particular, 97-131
- bath, requisites of a, 184
- chemical products and various apparatus and instruments used in, 493-522
- establishment, ground plan of an, 125-129
- establishments in general, arrangement of, 93-131
- industry, lacquers used in the, 484, 485

- Electro-plating, mechanical treatment during and after, 156-161  
 plant, parts of, 97  
 tanks, Bossard, 178-180  
 small articles en masse, apparatus for, 213-217  
 treatment of metallic articles before, 132-156
- Electrodes, 26
- Electrolysis, 25-33  
 consumption of power in, 33  
 determination of copper in copper  
   baths by, 277, 278  
   gold in gold  
     baths by, 372  
   silver in silver  
     baths by, 336, 337  
   zinc in brass  
     baths by, 290, 291
- Electrolyte, 26
- Electrolytic determination of copper  
 in the acid copper bath, 426, 427  
 dissociation, Svante Arrhenius' theory of, 27-29  
 method of analysis, 253-255  
 plating apparatus for mechanical electro-plating, 180
- Electropoison, 43
- Electroscope, 13
- Element, bichromate, 58  
 cupron, 53, 54  
 Daniell, 38, 39  
 described by Knafte and Keefer, 55, 56  
 Dun's potash, 54, 55  
 galvanic, 16  
 Grove, 40  
 Leclanché, 51  
 Meidinger, 39, 40  
 Oppermann, 47-51  
 plunge, 59, 60  
 Smee, 37, 38  
 Stoerer's, 59  
 Umbreit and Matthes, 53, 54
- Elements, arrangement with, 97-115  
 Bunsen, manipulation of, 45, 46  
 constant, 38  
 coupling of, for electro-motive force or tension, 20  
   quantity of current, 20  
 galvanic, 35-60  
 mixed coupling of, 20
- Elements, secondary, 87-92  
 table of electro-motive force of, 527  
   with their symbols, atomic weights and specific gravities, 523  
 various, 54
- Elmore's process of producing copper tubes, 460
- Elsner's bronze bath, 292  
 tinning bath, 389
- Emery, kinds of, 144
- Endless belt machine or belt strapping attachment, 153, 154
- English horse-power, 34
- Essential resistance, 18
- Etching, electro, 445-447  
 in steel for the production of dies for coins, reliefs, etc., 448, 449  
 ground, 446, 447
- Ether, definition of, 15
- Evaporating dishes or capsules, 517, 518
- External resistance, 18
- Extra currents, 25
- Eyes, silvering of, 325  
 tinning solution for, 388
- F**AHRENHEIT, Centigrade and Réaumur thermometers, comparison of the scales of, and rules for converting one scale into another, 538
- Farad, the, 34
- Faraday, discovery by, 65, 66  
 of chemical action of the current by, 26  
 electric induction by, 4  
 electrolytic laws of, 30-32
- Faure, improvement of the accumulator by, 88
- Fein bichromate battery, 56, 57  
 dynamo, 73, 74
- Felt wheels, 143
- Ferric oxide, 155  
 sulphide, 500
- Ferrous sulphate, 510
- Fibre brush, 146
- Fibres, 146, 147
- Field, magnetic, 12, 66  
 magnets, 67
- Filters, 520, 521
- Fine wheel, 144
- Fire gilder's brush, 136  
 -gilding and electro-deposition, combination of, 369-371

- Fire or mercury gilding, 367-369  
 Flasks, glass, 517  
 Flexible shafts for grinding, polishing and buffing, 154, 155  
 Flowers, coating of, with copper, 461  
 Foot-lathe for polishing, 149  
   -power grinding and polishing lathe, 150  
 Foote's pinnacle gravity battery, 46, 47  
 Force or power, 33  
 Forks, extra coating of silver on the convex surfaces of, 319  
   silver deposit on, 311  
   slinging wires for, 310  
 French form of cell-apparatus, 416, 417  
   horse-power, 34  
 Fulminating gold, 503  
 Fundamental or C. G. S. units, 33, 34
- G**ALVANI, discovery of contact electricity by, 1  
   experiments of, 1, 2  
 Galvanic chain, 16  
   current, 16  
   element, 16  
   elements, 35-60  
     thermopiles, magneto- and dynamo-electric machines, 35-92  
 Galvanometer, 103, 104  
   indications by the, 106-108  
 Galvanometers, 22  
 Galvanoplastic art, progress of, 5  
   baths at rest and when agitated, table of results with, 422  
   current-strength for, 437  
   copper baths, contrivances for the agitation of, 423, 424  
   deposition by the battery and dynamo, 418-425  
   in the cell-apparatus, 413-418  
   with accumulators, 438, 439  
   the battery, 419, 420  
     dynamo, 420-425  
   method for originals in high relief, 458  
   operator, pencils and brushes used by the, 136  
   process, invention of, 5  
   reproduction of busts, vases, etc., 449-455  
 Galvanoplasty, 412-468  
   definition of, 412  
   in iron, 463-467  
     nickel, 467  
     silver and gold, 467, 468  
   matting by, 166  
 Galvanoscopes, 22
- Gas carbon, 41, 42  
   anodes, 199, 200  
 Gassiot's method of producing metallo-chromes, 399  
 Gauduin's copper bath, 267  
 Gauze, gilding of, 358-360  
 Gelatine moulds, 458-460  
 Generators, electric, classes of, 69  
 Gerhold's solution for tinning, 387  
 German form of cell-apparatus, 417  
   silver articles, gilded, stripping of, 371  
     cleansing of, 171  
     deposit of, 248, 249  
     for spoons, preparation of, for plating, 318  
     nickeling of, 203  
     pickling of, 163  
     preparation of, for silver-plating, 308, 309  
     sheet, treatment of, 148  
     silver-plating of, 317  
 Gilded articles, stripping of, 371  
   to give a beautiful, rich appearance to, 357  
 Gilder of watch-works, brush used by the, 136  
 Gilder's wax, 356, 357  
 Gilding, bad tones of, to improve, 357, 358  
   by contact, baths for, 360-363  
     by immersion and by friction, 360-365  
     dipping, baths for, 363-365  
     friction, 366, 367  
   cold, baths for, 342-344  
   coloring of, 356-358  
   combination of fire-gilding and electro-deposition of, 369-371  
   defective, to improve, 363  
   fire or mercury, 367-369  
   genuine, determination, of, 371, 372  
   green, 354  
   hot, baths for, 344, 345  
   matt, 354-356  
   metallic wire and gauze, 358-360  
   preparation of articles for, 351  
   porcelain, glass, etc., 365, 366  
   red, 353, 354  
   rose-color, 354  
   spurious, of silvered brass articles, 478  
   with the cork, 366, 367  
     rag, 366, 367  
     thumb, 366, 367  
   without a battery, 350, 351  
 Girders, zinc-plating of, 393-395



- Glass balloons and flasks, 517  
 gilding of, 365, 366  
 jars, 518  
 metallization of, 463  
 platinizing of, 380, 381
- Glauber's salt, 509
- Glue pots, 153
- Gold amalgam, preparation of, 367  
 analyses of, 339  
 and silver, galvanoplasty in, 467, 468  
 baths, 341-346  
   current-density for, 350  
   strength for, 351  
   examination of, 372, 373  
   management of, 346-353  
   preparation of, with the assistance of the electric current, 345  
   recovery of gold from, 373, 374  
   strengthening of, 372, 373  
   vats for, 349, 350  
 capsule for discoloring, 361  
 chloride, 503  
 color, pale, on brass, 475  
 deposition of, 339-374  
 deposits, polishing of, 160, 353  
 in gold baths, determination of, by electrolysis, 372  
 incrustations with, 329, 330  
 painter's, 340  
 -plating, execution of, 350-353  
   in the cold bath, process of, 352  
   hot bath, process of, 352, 353  
   use of carbon anodes in, 348  
   platinum anodes in, 348  
   steel anodes in, 346-348  
 properties of, 339, 340  
 scratch-brushing of, 157  
 shell, 340  
 solder, 531  
 varnishers, operations of, 485, 486
- Gore, bath for brassing cast-iron, wrought-iron and steel, recommended by, 284, 285
- Gountier's solution for coating wrought- and cast-iron with bronze, 292
- Goze's process for obtaining a deposit of aluminium, 408
- Graining, 326-329  
 preparations for, 327
- Gramme armature, 70  
 dynamo, 8, 70, 71
- Grasses, coating of, with copper, 461
- Gravimetric analysis, 251, 252
- Gray color with a bluish tinge on brass, 475  
 yellow, brown to black colors on zinc, 480
- Gray's researches, 13
- Grease, removal of, from metallic articles, 169-171
- Green gilding, 354  
 vitriol, 510
- Grinding, 142-144  
 and polishing foot power lathe, 150  
 lathes electrically driven, 152  
 execution of, 146  
 flexible shafts for, 154, 155  
 lathes, 145-147  
   transmission for, 97  
 rooms used for, 96, 97  
 wheels, treatment of, 144, 145  
 wooden, 142, 143
- Grove element, 40
- Gülcher's thermo-electric pile, 63-65
- Gun barrels, browning of, 481, 482  
 metal, 280
- Gutta-percha, introduction of, 5  
 moulding in, 428-431  
 oil, 451  
 softening of, 428-431
- H**AEN'S method for the volumetric determination of copper in the acid copper bath, 425, 426
- Hansen & Van Winkle Co.'s dynamo, 82-85  
 lathe manufactured by, 150-152  
 plating-room arranged by, 129  
 voltmeter, 121
- Hard nickeling, baths for, 242, 243  
 solder, 530
- Hassauer's copper bath, 262
- Hauck's thermo-electric pile, 62, 63
- Heads, moulding of, 450, 451
- Hefner-Altenbeck's drum armature, 74  
 machine, 8
- Heliography, 447, 448
- Helix, 12
- Herz, Prof., investigations of, 15
- Historical review of electro-metallurgy, 1-9
- Hittorf's experiments, 29
- Hoe & Co.'s electric connection gripper, 435

Hollow ware, gilding of, 352  
 preparation of, for plating, 318

Hooks, silvering of, 325  
 tinning solution for, 388

Horizontal galvanometer, 103

Horse-power, English, 34  
 French, 34

Hot gilding, baths for, 344, 345

Hübl, experiments of, 412, 413

Hydraulic moulding press, 430, 431

Hydrochlorate of zinc, 501

Hydrochloric acid, 494

Hydrocyanate of silver, 506  
 zinc, 500

Hydrocyanic acid, 494, 495  
 poisoning by, 490, 491

Hydro-electric current, 16

Hydrofluoric acid, 496, 497

Hydrogen sulphide apparatus, construction of a, 67-69

Hydrometer, estimation of the condition of baths by the, 175, 176

Hydrometers, 518-520

Hydroplatinic chloride, 503, 504

Hydrosulphate of ammonia, 499

Hydrosulphuric acid, 498

Hygienic rules for the work shop, 489-492

Hypnotic gas, poisoning by, 492

**I**DIO-ELECTRICS, 13  
 Incrustations with silver, gold and other metals, 329, 330

Induced current, 24

Induction, 23-25  
 electric, discovery of, 4

Inductive current, 24

Inlaying of coppered art-castings, 274

Instruments and apparatus, various, 517-522

Internal resistance, 18

Ions, division of, 27, 28

Iridescent colors, 397-399

Iridium, deposition of, 382

Iron-ammonium sulphate, 510  
 articles, badly rusted, to cleanse, 162  
 copper baths for, 262  
 coppering of, 273  
 grinding of, 147, 148  
 pickling of, 162  
 silvered, stripping of, 333  
 tinning solution for, 388

baths, 400-402  
 management of, 402, 403  
 black color on, 482, 483

Iron, blue color on, 483  
 brassed, brown black color on, 476  
 brassing of, 283  
 brown-black coating with bronze lustre on, 483, 484  
 cast, brassing bath for, 284, 285  
 solution for coating with bronze, 292  
 tin-bath for, 384  
 zincking bath for, 392

castings, unground brassing of, 289

clock cases, dead black coating on, 483

coloring of, 481-484

current-density for nickeling, 206

deep black deposit of, 401, 402

deposition of, 399-403

deposits, analysis of, by Lenz, 464

electro-deposition of, principal use of, 399

electrolytically deposited, 466

excellent pickle for, 162

galvano plasty in, 463-467

heavy and very hard deposit of, bath for, 400

lustrous black color on, 482

nickel bath for, 195

nickeling of, 203, 204

objects, cleansing of, 171

sheet, coppering of, 271  
 nickeling of, 237, 238

silvering of, early knowledge of, 1

silver-plating of, 816

to give to, a silvery appearance with high lustre, 484

wire and plates, table of weight of, 536

wrought, brassing bath for, 284, 285  
 solution for coating with bronze, 292  
 zincking bath for, 392  
 of, by contact, 395  
 zinc-plating objects of, 393-395

**J**ACOBY, Prof., invention of the galvano-plastic process by, 5

Jars, glass, 518

Jordan, C. J., claim of, to the invention of the galvano-plastic process, 5

Joule's experiments, 32

**K**AISER, deposition of an alloy containing nickel according to, 247

- Kations, 26, 28  
 Keiser and Schmidt's bichromate battery, 57  
 Kettles, 181  
 Klein's bath for galvano-plasty in iron, 464  
     method for the production of copper tubes, 460, 461  
 Knaffe and Kiefer, element described by, 55, 56  
 Knife blades, nickeling of, 240, 241  
 Knight's process of black-leading, 433, 434  
 Knives, silver deposit on, 310, 311  
 Koffler's sheet polishing machine, 228-230  
 Kristaline, 487, 488  
 Kröttlinger dynamo, 76, 77  
 Krupp-Gousonwerk sheet polishing machine, 230-232  
  
**L** ACES, coating of, with copper, 460  
     Lacquering, 484-488  
 Lacquers and varnishes, cellulose, 487, 488  
     application of, 485  
 Lahmeyer dynamo, 77-89  
 Lallande and Chaperon element, 51-53  
 Lamp feet, cast zinc, nickeling of, 209  
 Langbein & Co., apparatus for electro-plating small articles, 214  
     dynamo, 79, 89  
     plunge element, 59, 60  
 La Pierre patent sand blast, 137  
 Lathe-brush for scratch-brushing, 159  
     foot-power for polishing, 149  
     grinding and polishing, 150  
     , manufactured by the Hanson & Van Winkle Co., 150-152  
 Lathes, double polishing, 150  
     grinding, 145-147  
     and polishing, electrically driven, 152  
     transmission for, 97  
 Law, Coulomb's, 15  
     Ohm's, 17, 18  
 Lead acetate, 517  
     baths, 397  
     cleansing of, 171  
     deposition of, 396-399  
     nickeling of, 203  
     salts, poisoning by, 491  
 Leading by contact, 397  
 Leather, plates for the production of imitations of, 462  
  
 Leaves, coating of, with copper, 461  
     metallization of, 455-457  
 Leclanché element, 51  
 Lenoir's galvanoplastic method for originals in high relief, 458  
 Lenz's analysis of iron deposits, 464  
 Liebenow and Loeb's theory of the accumulator, 90, 91  
 Lignite, 210  
 Lime, burnt or quick, 498  
     mixture or paste, preparation of, 170  
     Vienna, 498  
 Line, neutral, 11  
 Lines of force, 66  
 "Little Wonder" dynamo, 81  
 Liver of sulphur, 498, 499  
 Loadstone, 10  
 London Metallurgical Co., arcas silver-plating, patented by, 306-308  
 Lunar caustic, 514, 515  
  
**M**ACHINE, to find the speed of a, 537, 538  
 Magnet, artificial, 10  
 Magnetic field, 12, 66  
     iron ore, 10  
     machine, 7  
     meridian, 11  
     needle, determination of the direction of the, 21  
     poles, 10, 11  
 Magnetism, 10-12  
     Ampère's theory of, 11, 12  
     and electricity, 10-34  
 Magneto- and dynamo-electric machines, 65-87  
     -electric machine, transition of the, to the dynamo, 68  
 Magnets, field, 67  
 Mannesmann Pipe Works, process of the, for deposits upon aluminium, 411  
 Marble, 508  
 Matrices in plastic material, preparation of, 427, 428  
 Matt-black on copper, 471, 472  
     -gilding, 354-356  
     -grained surface, production of a, 165  
 Matting, 164-166  
     by chemical means, 165  
     galvanoplasty, 166  
     mechanical means, 165, 166  
 Mechanical electroplating, electrolytic plating apparatus for, 180  
     treatment during and after electro-plating, 156-161

- Mechanical treatment of metallic articles, 132-161
- Mechano electro-plating tanks, Bossard, 178-180
- Medium wheel, 144
- Meidinger element, 39, 40
- Mercuric nitrate, 514
- Mercurous nitrate, 514
- Mercury or fire-gilding, 367-369  
salts, poisoning by, 491
- Meriden Britannia Co's practice of silver-plating, 317, 318  
silver-plating solution, 318  
striking solution, 318
- Meridian, magnetic, 11
- Meritens's process of coloring iron black, 482, 483
- Metal, regaining of, from exhausted dipping baths, 168, 169
- Metallic alloys for moulds, 452  
articles, chemical treatment of, 161-172  
mechanical treatment of, 132-161  
removal of grease from and cleansing, 169-171  
treatment of, 132-172  
before electro-plating, 132-156  
chromes, 397-399  
powders, metallization by, 457, 458  
surface, making a copy from a, 444, 445
- Metallization by metallic powders, 457, 458  
the wet way, 455-457
- Metals, coloring, patinizing, oxidizing, etc., of, 469-488  
conducting power of, 17  
incrustations with, 329, 330  
reduction of, without a battery, 184, 185  
table of melting points of, 531
- Milk pitchers, gilding of, 352
- Mineral kermes, 479
- Molecules, Clausius' theory of, 26, 27
- Monopotassic carbonate, 507
- Montgomery, Dr., introduction of gutta-percha by, 5
- Motors, directly connected, to machines, 85, 86
- Mould, detaching the shell from the, 439
- Moulding busts, 450, 451
- Moulding compositions, 431  
heads, 450, 451  
in gutta-percha, 428-431  
wax, 431  
press, 429, 430  
hydraulic, 430, 431  
surfaces in relief, 450  
with metallic alloys, 452  
oil gutta-percha, 451, 452
- Moulds, black-leading of, 431-434  
gelatine, 458-460  
in plastic material, preparation of, 427, 428  
suspension of, in the bath, 435, 436
- Multipliers, 22
- Muriate of gold, 503  
zinc, 501
- Muriatic acid, 494
- Murray, discovery by, of making non-metallic surfaces conductive, 5
- N**AILS, zincking of, 395  
Nature-printing, 460
- Needles, tinning of, 389
- Nees's process for electro-depositions upon aluminium, 411
- Negative electricity, 13  
wire, 109
- Neutral line, 11  
zone, 11
- Nicholson and Carlisle, decomposition of water by electrolysis by, 3
- Nickel alloys, deposits of, 247-249  
ammonium sulphate, 512  
and cobalt, deposition of, 186-260  
anodes, 198-202  
reddish tinge of, 202  
bath, arrangement of anodes for a, 208, 209  
coupling of Bunsen elements for a, 98  
for production of thick deposits, 196, 197  
small articles, 196  
most simple, 190  
without nickel salt, 198
- baths, 187-198  
addition of bisulphide of carbon to, 196  
containing boric acid, 192-194  
determination of acidity and alkalinity of, 189, 190  
acids in, 249, 250  
electrolytic analysis of, 255



- Nickel baths, examination of, 249-256  
 first requisite in preparing, 187  
 for special purposes, 194-196  
 freshly-prepared, working of, 197  
 heating of, 198  
 old, recovery of nickel from, 244  
 refreshing of, 220, 221  
 restoring the neutrality of, 202  
 wooden vats lined with lead for, 110, 111  
 bronze, 247, 248  
 carbonate, 509  
 chloride, 502  
 copper and zinc, deposition of an alloy of, 248  
 deposition of, 186-256  
     from its double salt, 6  
 deposits, polishing of, 160, 221  
 electrotypes, 467  
 galvanoplasty in, 467  
 patent for the deposition of, 6  
 plating, additional rules for, 209, 210  
     criteria for the correct progress of, 206  
     current-strength for, 205, 206  
     principal phenomena, which may occur in, and their avoidance, 218-220  
     process of, 202-211  
     solid, 207  
     test for sufficiently solid, 208  
     treatment of articles after, 221  
     yellowish tone of, remedy for, 218  
 properties of, 186, 187  
 salts, solution of, 181, 182  
 scratch-brushing of, 157  
 silver for spoons, preparation of, for plating, 318  
     -plating of, 317  
 solutions, eruptions caused by, 490  
 sulphate, 511, 512  
 various colors upon, 473, 474  
 Nickeled articles, removal of moisture from, 159, 160  
     stripping of, 217, 218  
 Nickeling, 186-256  
     by contact and boiling, 245-247  
     defective, to improve, 244, 245  
     electrotypes, 242-244  
 Nickeling en masse of small and cheap objects, 211-217  
     hard, baths for, 242, 243  
     knife blades, sharp surgical instruments, etc., 240, 241  
     of a dark tone, bath for, 195  
     printing plates, 242-244  
     salts, prepared, 187  
     sheet iron and sheet steel, 237, 238  
     zinc, 221-236  
     skates, 241, 242  
     tin-plate, 236  
     wire, 238-240  
     gauze, 240  
 Niel, imitation of, 330, 331  
 Niello, Corvin's, 461  
 Nitrates, 513-515  
 Nitre, 513, 514  
 Nitric acid, 494  
     table of specific gravity and content of, 533  
 Nitrous gas, poisoning by, 492  
 Nobili, production of iridescent colors by, 4  
 Nobili's rings, 397-399  
 Noe's thermo-electric pile, 61  
 Non-electrics, 13  
     -essential resistance, 18  
 Norris and Johnson's brass bath, 284, 285  
 North pole, 11  
 OBERNETTER'S method of steeling copper printing plates, 400, 401  
 Object-wire, 109  
     main, and main anode wire, coupling of the, with the resistance boards, voltmeter, switch and baths, 123, 124  
 Oersted, Prof., discoveries of, 3, 4  
 Ohm, the, 34  
 Ohm's law, 4, 17, 18  
     proposition deduced from, 20, 21  
 Oil gutta-percha, 451  
 Oil of vitriol, 493, 494  
 Opperman element, 47-51  
 Organic acids, salts of, 516, 517  
 Orpiment, 499, 500  
 Osmotic pressure, 29  
 Oxalate platinum bath, 378  
 Oxidized silver, 332  
 Oxidizing, patinizing, coloring, etc., of metals, 469-488

- PACINOTTI**, invention by, of the ring named after him, 8  
 ring armature of, 68
- Painter's gold**, 340
- Palladium baths**, 382  
 deposition of, 381, 382  
 properties of, 381, 382
- Paracelsus**, silvering of iron and copper known to, 1
- Paris Mint**, method in the, for producing brown color upon copper, 470
- Parkes's method of metallization**, 455-457
- Pasteboard wheels**, 143
- Pastes**, argentiferous, for cold silvering, 326
- Patent Underwriter's switch board or rheostat**, 104, 105
- Patina**, definition of, 469  
 genuine, imitation of, 472, 473
- Patinizing**, oxidizing, coloring, etc. of metals, 469-488
- Pfanhauser's brassing bath**, 285, 286  
 copper bath, 267  
 plating drum, 214, 215  
 tin bath, 385
- Philipp's process of coating laces and tissues with copper**, 460
- Phosphate platinum bath**, 378, 379
- Phosphates and pyrophosphates**, 515
- Pickle for iron**, 162  
 preliminary, 163
- Pickling**, 115  
 absorbing plant for the vapors evolved in, 167, 168  
 and dipping, 162-164  
 duration of, 162, 163  
 in the electrolytic way, 162  
 main points in, 166, 167  
 production of a matt-grained surface by, 165
- Pile of Volta**, 2, 35
- Piles**, thermo electric, 60-65
- Pillet's palladium bath for watch-movements**, 382
- Pins**, nickeling of, 211  
 silvering of, 325  
 tinning solution for, 388
- Pitchers**, gilding of, 352
- Pixii**, construction of the first electromagnetic-induction machine by, 4  
 electrical machine constructed by, 68
- Planté accumulators**, 87, 88
- Plaster of Paris**, making of, impervious to fluids, 454, 455
- Plaster of Paris**, moulding in, 452-454
- Plater's lathe goblet scratch-brush**, 134
- Plating balance**, 312-314  
 drum, 214, 215  
 room arranged by the Hanson & Van Winkle Co., 129  
 floor of, 95  
 heating of, 94, 95  
 light and ventilation in, 93, 94  
 size of, 96  
 water for, 95
- Platinic chloride**, 503, 504
- Platinizing by contact**, 381  
 glass, 380, 381
- Platinum anodes**, 199  
 insoluble, 299, 300  
 use of, in gold-plating, 348
- baths**, 375-379  
 management of, 379, 380  
 deposition of, 375-381  
 deposits, polishing of, 160  
 -plating, execution of, 380  
 properties of, 375  
 recovery of, from platinum solutions, 381
- Platino-ammonium chloride**, preparation of, 375
- Plunge batteries**, 56  
 element, 59, 60
- Poisoning by alkalis**, 491  
 arsenic, 491  
 copper salts, 491  
 chlorine, sulphurous acid, nitrous and hyponitric gases, 492  
 hydrocyanic acid, potassium cyanide or cyanides, 490, 491  
 lead salts, 491  
 mercury salts, 491  
 sulphuretted hydrogen, 491, 492
- Polarizing current**, 27, 210, 211  
 formation of, 30  
 phenomena, 210, 211  
 prevention of, 37
- Pole**, north, 11  
 pieces, 67  
 south, 11
- Poles**, attraction and repulsion of, 11
- Polishing**, 148-156  
 copper deposits, 270, 271  
 dust in, prevention of, 97  
 flexible shafts for, 154, 155  
 gold deposits, 353

- Polishing lathes, double, 150  
 materials, 155, 156  
 nickel deposits, 221  
 rooms used for, 96, 97  
 wheels or hobs, 148, 149
- Poole, M., first use of thermo-electricity by, 6
- Porcelain, deposit of copper upon, 463  
 gilding of, 365, 366  
 metallization of, 463
- Positive electricity, 13  
 wire, 109
- Potash, 507  
 alum, 509, 510  
 bicarbonate of, 507  
 caustic, 497  
 element, Dun's, 54, 55  
 yellow, prussiate of, 506, 507
- Potassium and sodium amalgam, production of, 4  
 bitartrate, 516  
 carbonate, 507  
   in silver baths, determination of, 335  
   solutions, table of specific gravity and content of, 531  
 cyanide, 174, 504, 505  
   handling of, 490  
   free, in brass baths, determination of, 290  
   in silver baths, determination of, 334  
   in copper baths, determination of, 275-277  
   poisoning by, 490, 491  
   solutions, introduction of, 5, 6  
   use of as a pickle, 164  
   with a different content, table of, 505  
   discovery of, 3  
   ferro-cyanide, 506, 507  
   hydrate, 497  
   nitrate, 513, 514  
   -sodium tartrate, 516  
   sulphide, 498, 499
- Potential, 16, 33, 34
- Pottery, deposit of copper upon, 463
- Power, consumption of, in electrolysis, 33  
 or force, 33
- Press, moulding, 429, 430
- Pressure, osmotic, 29
- Primary current, 24
- Printing plates, copper, galvanoplastic bath for, 421  
 steeling of, 400, 401, 403
- Protosulphate of iron, 510
- Prussiate of potash, white, 504, 505  
 silver, 506  
 zinc, 506
- Prussic acid, 494, 495  
 poisoning by, 490, 491
- Pulley on counter-shaft carrying belt to machine, to find diameter of, 537  
 main shaft, to find diameter of, 537
- Pyrophosphates and phosphates, 515
- Q**UADRIVALENT kations, 28  
 Quantity, 33  
   of current, 17-21
- Quick lime, 498
- Quicking, 309
- R**AIN water, 173  
 Ratsbane, 496
- Räuber's sheet grinding and polishing machine, 224-228
- Réaumur, Centigrade and Fahrenheit thermometers, comparison of the scales of, and rules for converting one scale into another, 538
- Recovery of gold from gold baths, 373, 374  
 nickel from old baths, 244  
 platinum from platinum solutions, 381
- Red brass, 280  
 brown-color on copper, 471  
   dark, on brass, 477  
   shades on zinc, 481  
 gilding, 353, 354  
 sulphide of antimony, 499
- Region of the lines of force, 66
- Reinhold's aluminium bath, 408
- Relief, surfaces in, moulding of, 450
- Reliefs, dies for, production of, 448, 449
- Resinous electricity, 13
- Resist, composition of, 328
- Resistance, 16, 17, 34  
 -board, 101-103  
 total, composition of, 18
- Rheostat, 101-103  
 patent underwriters, 104, 105
- Rhodium, deposition of, 382
- Rieder's process of electro-etching in steel for the production of dies for coins, reliefs, etc., 448, 449
- Ring armature, Pacinotti's, 68
- River water, 173
- Rivets, nickeling of, 211
- Rochelle salts, 516
- Rock salt, 500

- Rods, plating apparatus for, 216  
 Rogers Manufacturing Co., amount of silver deposited upon plated table ware, manufactured by, 311  
 preparation of work for plating by, 318  
 silver-plating solution used by, 318  
 striking solution used by, 318
- Rose-color gilding, 354  
 Roseleur's plating balance, 312-314  
 solutions for tinning, 387  
 Rouge, 155  
 Roughing wheel, 144  
 Ruolz's bronze bath, 292
- SAL AMMONIAC**, 500  
 solutions, table of specific gravity of, 533
- Salt, common, 500  
 rock, 500  
 Saltpetre, 513, 514  
 Salts of organic acids, 516, 517  
 Salzède's bronze bath, 292  
 Sand-blast, matting with the, 166  
 -blasts, 136-139  
 Sawdust, 159  
 Saxton and Clarke, invention by, 68  
 Schaag's process of zincking, 391  
 Schlippe's salt, preparation of, 405  
 Schuckert dynamo, 8, 72, 73  
 Schultz's patent for prevention of stains in copper-plating, 270  
 Scratch-brushes, circular, 134, 135  
 forms of, 133, 134  
 -brushing, 133-136, 156-159  
 lathe-brush for, 159  
 liquids used in, 157
- Screws, zincking of, 395  
 Secondary current, 24  
 element, 87-92  
 Seebeck, Prof., discovery of, 60  
 Seignette salt, 516  
 Shafts, flexible, for grinding, polishing and buffing, 154, 155  
 Shaving machines for electro-plates, 443  
 Sheet iron, coppering of, 271  
 nickeling of, 237, 238
- Sheet polishing machines, 224-232  
 steel, nickeling of, 237, 238  
 zinc, coppering of, 271  
 nickeling of, 221-236
- Shell, backing the, 440-442  
 gold, 340
- Siemens, Dr. W., discovery by, 68, 69  
 improvement by, 68  
 & Halske dynamo, 8, 74-76
- Silver, amount of, deposited upon table ware, 311  
 and gold, galvanoplasty in, 467, 468  
 anodes, 298  
 articles, gilded, stripping of, 371  
 baths, 295-298  
 addition of potassium cyanide to, 300  
 silver to, 301  
 agitation of, 303, 304  
 augmenting the content of silver in, 302  
 "bright-plating," preparations for, 304, 305  
 coupling of elements for, 98  
 determination of the proper proportions of silver and potassium cyanide in, 302  
 examination of, 334-337  
 free potassium cyanide in, determination of, 334  
 gradual thickening of, 301, 302  
 improvement of, by organic substances, 305, 306  
 insoluble platinum anodes for, 299, 300  
 most suitable current-strength for, 299  
 old, recovery of silver from, 337-339  
 potassium carbonate in, determination of, 335  
 prepared with chloride of silver, life of, 301  
 silver in, determination of, 336, 337  
 strengthening of, 337  
 treatment of, 298-308  
 chloride, 502, 503  
 preparation of silver bath with, 296, 297  
 control of the weight of the deposit of, 311-314  
 cyanide, 506  
 preparation of silver bath with, 297  
 deposition of, 294-339



- Silver deposits, polishing of, 160  
 heavy deposits of, baths for, 295-297  
 in silver baths, determination of, 336, 337  
 incrustations with, 329, 330  
 -nickel alloy, deposit of, 306  
 nitrate, 514, 515  
 oxidized, 332  
 -plated articles, yellow tone of, 306  
 -plating, arcas, 306-308  
   balance, 312-314  
   by weight, 308-315  
     baths for, 295-297  
   determination of, 333, 334  
   execution of, 308-320  
   Meriden Britannia Co.'s practice of, 317, 318  
   ordinary, 315-320  
     bath for, 298  
   statistics of quantity of silver used in, 295  
 powder for graining, preparation of, 327  
 properties of, 294  
 recovery of, from old silver baths, 337-339  
 scratch-brushing of, 157  
 solder, 530  
 striking solutions, 318  
 Silvered articles, stripping of, 333  
   yellow color on, 332  
 Silvering, antique, 331, 332  
   articles of copper-alloys, 323-325  
   by contact, by immersion and cold silvering with paste, 320-326  
     immersion, baths for, 320, 321  
   cold, with paste, 325, 326  
   current-density for, 100  
   fine copper wire, 329  
   nielled, imitation of, 330, 331  
   old, 331, 332  
 Similor, 280  
 Sine galvanometer, 22  
 Single fluid hypothesis of electricity, 14, 15  
 Siphons, 521, 522  
 Skates, nickeling of, 241, 242  
 Sliding wires, 114  
   for forks and spoons, 310  
 Smee, discoveries of, 6  
   element, 37, 38  
   experiments by, 412  
 Smith & Deakin, apparatus of, for electro-plating small articles, 313  
 Smoke-bronze, 477  
 Soda, caustic, 497  
 Soda, washing, 507, 508  
 Sodium and potassium amalgam, production of, 4  
   bicarbonate, 508  
   bisulphite, 513  
   carbonate, 507, 508  
   chloride, 500  
   citrate, 517  
   discovery of, 3  
   hydrate, 497  
   nitrate, 514  
   phosphate, 515  
   pyrophosphate, 515  
   sulphate, 509  
     varieties of, 174  
   sulphide solution, preparation of, 321-323  
   sulphite, 513  
 Soft solder, 530  
 Soldering fluid, 440, 441  
 Solders, table of, 530, 531  
 Solenoid, 12, 23  
 Solubility of various substances, table of, 528  
 Sources of current, 35-92  
 South pole, 11  
 Sparking, causes of, 116  
 Specific gravity, estimation of the condition of baths by the, 175, 176  
 Speed, rules for, 537, 538  
 Spencer, T., claim of, to the invention of the galvanoplastic process, 5  
   electro-etching, invented by, 445  
 Spirit of nitre, 494  
 Spirits of hartshorn, 497, 498  
 Spoons, extra coating of silver on the convex surfaces of, 319  
   sliding wires for, 310  
   silver deposit on, 311  
 Spring water, 173  
 Stannic chloride, 501  
 Stannous chloride, 501  
 Starrett improved volt-meter, 120  
 Stearine, moulding in, 431  
 Steel anodes, use of, in gold-plating, 346-348  
   articles, cleansing of, 171  
     cobalt bath for, 258, 259  
     copper bath for, 262  
     coppering of, 273  
     grinding of, 147, 148  
     tinning solution for, 388  
   bath for brassing, 284, 285  
   for zincking, 392  
   baths, 400-402  
   blue color on, 483

- Steel clock cases, dead black coating on, 483  
 current-density for nickeling, 206  
 cutlery, preparation of, for plating, 318  
 electro-etching in, for the production of dies for coins, reliefs, etc., 448, 449  
 galvanoplasty in, 463-467  
 gray color upon brass, 475  
   copper, 473  
 nickeling of, 203, 204  
 pens, coppering of, 273, 274  
 sheet, nickeling of, 237, 238  
 silver-plating of, 316, 317, 318  
 spring carboy rocker, 172
- Steeling, 399-403  
   by contact, 403
- Stoerer's element, 59
- Stolbe's method of tinning, 390  
   nickeling process by contact, 245, 246
- Stone-ware, deposit of copper upon, 463  
   vats, 112
- Stopping off, 319, 320
- Straw color to brown, through golden yellow, and tombac color on brass, 475
- Striking solutions, 318
- Stripping acid, 217  
   gold from gilded article, 371, 372  
   nickeled articles, 217, 218  
   silvered articles, 333
- Sugar of lead, 517
- Sulphate of iron, 510
- Sulphates and sulphites, 509-513
- Sulphur combinations, 498-500
- Sulphuretted hydrogen, 498  
   poisoning by, 491, 492
- Sulphuric acid, 493, 494  
   free, determination of, 250  
   solutions, different, table of specific electrical resistances of, at various temperatures, 526  
   table of specific gravity of, 532
- Sulphurous acid, poisoning by, 492
- Sulphydrate of ammonia, 499
- Sulphydric acid, 498
- Surgical instruments, coating the wooden handles of, with copper, 462, 463  
   sharp, nickeling of, 240, 241
- Svante Arrhenius's theory of electrolytic dissociation, 27-29
- Swing brush, 133, 134
- Switch-board, 101-103  
   Patent Underwriters', 104, 105
- TABLE for freeing articles from grease, 127, 128  
 of actual diameters in decimal parts of an inch corresponding to the numbers of the various wire gauges, 535  
 approximate content of blue vitriol in solutions at different degrees Bé, 417, 418  
 chemical and electro-chemical equivalents, 524, 525  
 composition of alloys and solders, 528-531  
 electrical resistance of pure copper wire of various diameters, 534  
 electro-motive force of elements, 527  
 elements, with their symbols, atomic weights and specific gravities, 523  
 high temperatures, 531  
 melting points of some metals, 531  
 potassium cyanide with a different content, 505  
 readings of different hydrometers, 519  
 resistance and conductivity of pure copper at different temperatures, 534  
 results with galvanoplastic baths at rest, and when agitated, 422  
 solubility of various substances, 528  
 specific electrical resistances of different sulphuric acid solutions at various temperatures, 526  
 gravity and content of nitric acid, 533  
 of and content of solutions of potassium carbonate, 531  
 of sal ammoniac solutions, 533

- Table of specific gravity of sulphuric acid, 532  
 resistance of different copper sulphate solutions at various temperatures, 526  
 value of equal current volumes as expressed in ampères per square decimeter, per square foot, and per square inch of electrode surface, 525, 526  
 weight of iron, copper and brass wire and plates, 536
- Tables, useful, 522-538
- Table-ware, plated, amount of silver deposited upon, 311
- Tangent galvanometer, 22
- Tanks, Bossard mechano-electroplating, 178-180  
 or vats, 109-112
- Tartar emetic, 516
- Taucher's bath for gilding by contact, 360-363  
 tin bath, 385, 386
- Temperatures, high, table of, 531
- Terchloride of gold, 503
- Terra-cotta metallization of, 463
- Thermo-electric poles, 60-65  
 electricity, first use of, 6
- Thermometers, coating mercury vessels of, with copper, 463  
 Fahrenheit, Centigrade and Réaumur, comparison of the scales of and rules for converting one scale into another, 538
- Thompson, Prof. S. P., definition of a dynamo electric machine by, 67
- Tin articles, silver-plating of, 316  
 baths, 383-386  
 current for, 386  
 management of, 386, 387  
 refreshing of, 386  
 chloride, 501  
 coloring of, 484  
 deposition of, 383-390  
 deposits polishing of, 160  
 durable coating of, 389  
 -plate, nickeling of, 236  
 -plating, process of, 387  
 properties of, 383  
 salt, 501  
 choice of, 386  
 zinc, lead and iron, deposition of, 383-403
- Tinning by contact and boiling, solutions for, 387-390
- Tissues, coating of with copper, 460
- Toggle press, 429, 430
- Tombac, 280  
 articles, silvered, spurious gilding of, 478  
 cleansing of, 171  
 deposits of, 293  
 nickeling of, 203  
 pickling of, 163
- Tripoli, 155
- Trivalent anions, 28  
 kations, 28
- Trough battery, Cruikshank's, 2, 3, 35
- Tumbling barrel, adjustable oblique, 141, 142  
 or drum, 139-141
- Twaddle hydrometer, 519
- U**MBEREIT and Matthes element, 53, 54
- Union canvass wheel, 149
- United States, evolution of the dynamo for plating purposes in the, 80-82
- Units, electric, 33, 34
- Univalent anions, 28  
 kations, 28
- V**ARNISH, stopping off, 319, 320  
 Varnishes and lacquers, cellulose, 487, 488  
 composition of, 486, 487  
 for gold varnishers, 486
- Varrentrapp's iron bath, 400
- Vases, galvanoplastic reproduction of, 449-455
- Vats and tanks, 109-112  
 for heating baths, 112  
 or tanks, 109-112  
 wooden, 109, 110  
 lined with lead, for copper and nickel baths, 110, 111
- Verdigris, 516, 517
- Vertical galvanometer, 103, 104
- Vienna lime, 145, 155, 498
- Villon's process for electro-depositions upon aluminium, 410, 411
- Violet color on brass, 477, 478
- Vitreous electricity, 13
- Vitriol, blue, 510, 511  
 green, 510  
 white, 511
- Volt, the, 34
- Volta, A., 1, 2
- Voltaic pile, 2, 35

Voltmeter. Hanson & Van Winkle, 121  
Starrett improved, 120

Voltmeters, 118-123

Volumetric analysis, 252, 253

determination of copper in acid  
copper  
bath, 425,  
426

in copper  
baths, 278-  
280

zinc in brass  
baths, 291

**WAHL, DR. W. H.**, directions for  
preparing platinum baths by,  
375-379

Walenn's copper bath, 266, 267

Walrine wheel, 149

Walrus-hide wheels, 147, 148

Warren's cobalt solution, 258

Washing soda, 507, 508

Watch-movements, plating of, with  
palladium, 382

Watches, graining parts of, 326, 327

Water, 173

decomposition of, by electro-  
lysis, 3

power of dissociation of, 28

Watt, the, 34

Wax, gilder's, 356, 357

moulding in, 431

Weil and Newton's bronze bath, 292

Weil's copper bath, 266

method of zincing, 396

Weiler, L., conducting power of met-  
als according to, 17

Well water, 173

Weston ammeter, 121, 122

boric acid as an addition to baths  
recommended by, 188, 189

dynamo, 81

nickel bath, 192

voltmeter, 121

Wheatstone, Sir C., discovery by, 68,  
69

Wheel. Union canvass, 149

walrine, 149

Wheels, grinding, 142-144

treatment of, 144, 145

polishing, 148, 149

walrus-hide, 147, 148

White arsenic, 496

metal, silver-plating of, 317

prussiate of potash, 504, 505

vitriol, 511

Whiting, 508

Wilde machine, 8

Wire, anode, 109

-carriers, special, 117

copper, silvering of, 329

current-carrying, size of, 108

-gauges, table of actual diameters  
in decimal parts of an inch cor-  
responding to the numbers of  
the various, 535

gauze, nickeling of, 240

gilding of, 358-360

negative, 109

nickeling of, 238-240

positive, 109

Wires, conducting, calculating the  
thickness of, for dyna-  
mos, 129, 131

insulation of, 109

slinging, for forks and spoons, 310

Wollaston, discovery by, 3

Wood, coating of, with copper, 462

Wooden grinding wheels, 142, 143

vats, 109, 110

Woolrych, first magnetic machine,  
constructed by, 7

Work, 33

Workshop, hygienic rules for the,  
489-492

Wright, introduction by, of the use of  
potassium cyanide solutions, 5, 6

Wrought iron articles, pickling of, 162  
zinc-plating of, 393-  
395

bath for brassing, 284,  
285

zincing, 392

solution for coating of,  
with bronze, 292

**YELLOW** brass, 280

-brown shades on zinc, 481

color on bronze articles, 476, 477

silvered articles, 332

prussiate of potash, 506, 507

**ZAPON, 487**

Zilken's solution for tinning, 388

Zinc alloys, production of, by the  
galvanic method, 396

amalgamation of, 36, 37

articles, copper bath for, 263, 264

nickel bath for, 195

pickling of, 163

bath for brassing, 284

baths, 391-393

brassed, brown-black color on, 476

bronzing on, 481

carbonate, 508, 509

castings, nickel bath for, 195



- Zinc castings, treatment of, 148  
 chloride, 501  
   and ammonium chloride, 502  
   qualities of, 174  
 coloring of, 479-481  
 cyanide, 506  
 deposition of, 390-396  
 gray coating on, 480, 481  
   yellow, brown to black colors  
   upon, 480  
 in brass baths, determination of,  
   by electrolysis, 290,  
   291  
   volumetric determination of, 291  
 plates, coating of, with a thin but  
   hard layer of copper, 272  
 -plating, execution of, 392-395  
   of wrought-iron objects, gird-  
   ers L-iron, T-iron, etc.,  
   393-395  
 properties of, 390, 391  
 red-brown shades on, 481  
 scratch-brushing of, 157
- Zinc sheet, anodes used in nickeling,  
 235  
 black streaks and stains in  
 nickeling, 235, 236  
 brassing of, 233, 234  
 cleansing of, 232, 233  
 coppering of, 234, 271  
 nickel bath for, 195  
 nickeling of, 221-236  
 preliminary grinding and  
 polishing of, 222  
 prevention of the peeling off  
 of the nickel deposit from,  
 233, 234  
 treatment of, 148  
 vats for nickeling, 234, 235  
 sulphate, 511  
 -tin alloy, deposition of, 396  
 -nickel alloy, deposition of,  
 396  
 yellow-brown shades on, 481  
 Zone, neutral, 11  
 Zosimus, reduction of copper from its  
 solution by iron described by, 1

## ELECTRO=PLATING OUTFITS

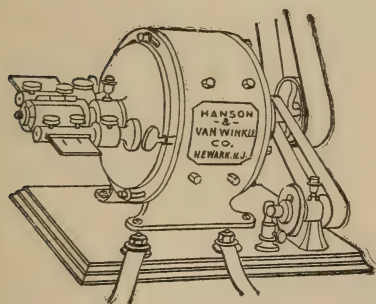
FOR

### Gold, Silver, Nickel, Copper, Etc.

#### Just a Word about Dynamos.

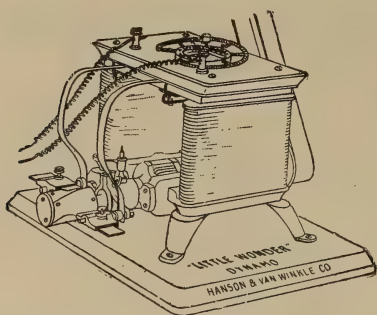
Did you know that all the early experiments and improvements in Dynamos were made with a view of perfecting an electrical machine for plating, and that this success was the forerunner of all the magnificent Dynamo machines for other purposes in such general use to-day?

In 1876 we began manufacturing the



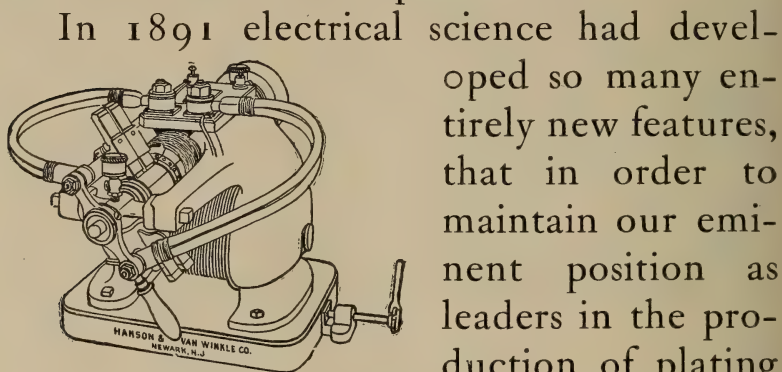
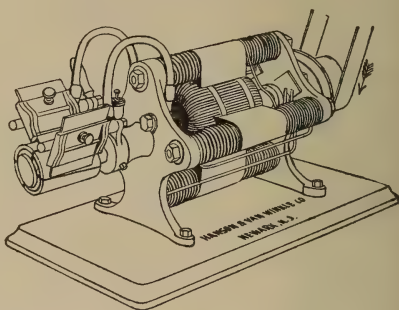
“Weston” Dynamo for electro-plating. This was the first machine in the market. It met with pronounced success, and to it can be traced the sudden

development of electro-plating and electro-typing. Many of these machines are still in use.



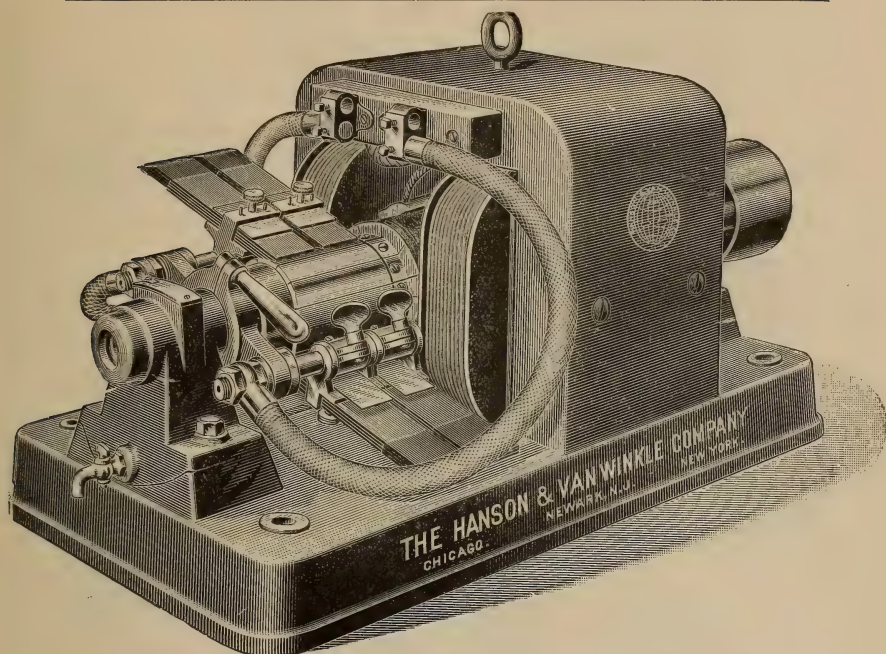
In 1885 we brought out the "Little Wonder" Dynamo. It became very popular. Over one thousand were sold.

In 1886 we began manufacturing the "Wonder" Dynamo. It embodied many new improvements, and we thought then that we had reached perfection.



In 1891 electrical science had developed so many entirely new features, that in order to maintain our eminent position as leaders in the production of plating machines, we brought out our H. & V. W. Dynamo. It embodied every late idea, and has had a remarkable sale.

(On the following page we show our new IRON CLAD Dynamo. This also marks a new era in plating dynamos.)



***If You are Interested***

in Electro-plating, Electrotyping, Electro-refining of Metals or other Electro-chemical operations, you will naturally feel interested in anything that tends to bring these industries to the highest stage of development.

***In Introducing***

this new dynamo to your notice, we feel that we are urging the claims of a machine which will materially aid you in reaching that point.

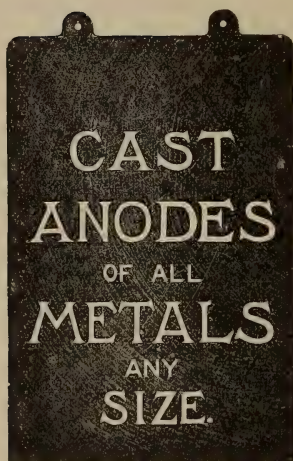
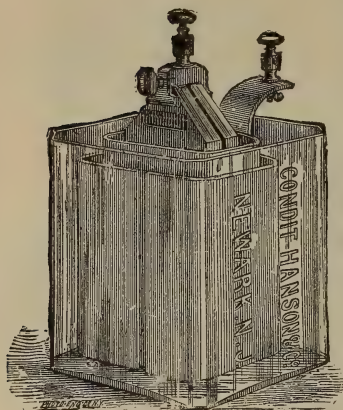
***Many***

who have only used the old style machines have no idea of the improvements that have recently been made in this class of dynamos; improvements that save time, money, labor and trouble.

***There are Several***

dynamos which are marked improvements on the old style of machines, but the new IRON CLAD, while embracing all the good points found in other modern machines, has several improvements distinctively its own, and is the result of years of experimenting; there are no unusual number of brushes as in some other Dynamos, in some requiring 24 to 36 brushes to wear the Commutator and the patience of the plater.





### **Nickel:**

We are first hands in nickel and other metals, and the largest manufacturers of the various Metallic Salts, of Nickel, Silver, Copper and Gold, and of Cyanide of Potassium.

### **Plating Solutions:**

We furnish Concentrated Plating Solutions of Silver, Gold, Copper, Nickel, Brass, etc.

### **Batteries**

of all kinds. Our No. 1 H. & V. W. Battery has had a larger sale than any other for Electro-Plating and experimental work.

### **Anodes:**

Our Cast Nickel Anodes are standard for whitest results. Anodes of Nickel, Silver, Gold, Electro-deposited Copper, Brass, etc. Nickel castings.

### **Tanks:**

Porcelain-lined, Iron, Wood, Slate, etc., for all purposes.

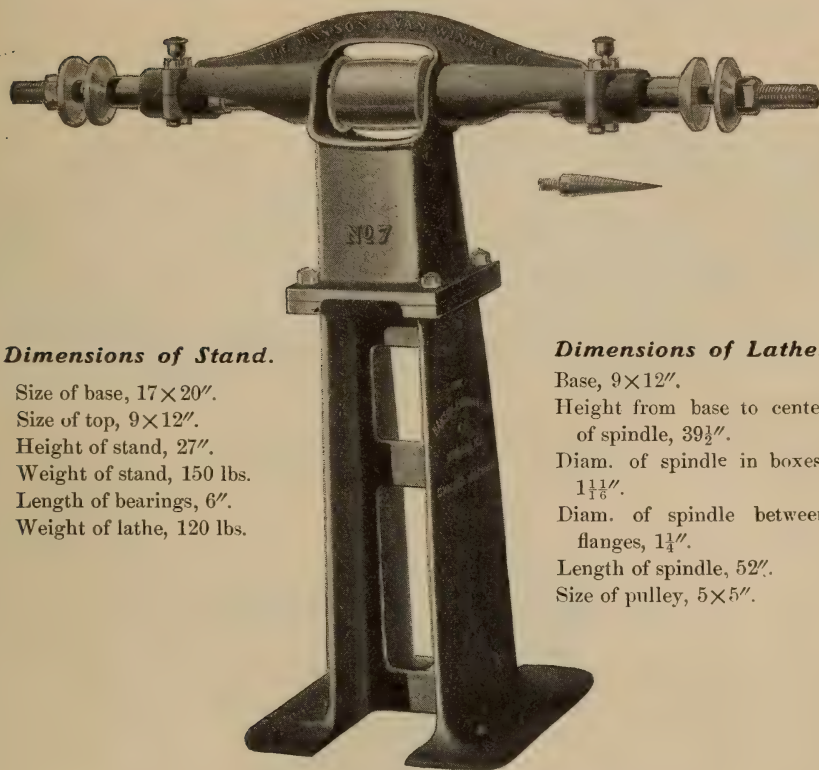
### **Lacquers:**

Patent Celluloid Lacquers for metal, paper, etc. Gold and colored Lacquers.

### **Chemical Solution:**

For removing sand, scale, etc., from castings, etc.

## No. 7. Polishing and Buffing Lathe.



### *Dimensions of Stand.*

Size of base,  $17 \times 20$ ".  
Size of top,  $9 \times 12$ ".  
Height of stand, 27".  
Weight of stand, 150 lbs.  
Length of bearings, 6".  
Weight of lathe, 120 lbs.

### *Dimensions of Lathe.*

Base,  $9 \times 12$ ".  
Height from base to center of spindle,  $39\frac{1}{2}$ ".  
Diam. of spindle in boxes,  $1\frac{1}{16}$ ".  
Diam. of spindle between flanges,  $1\frac{1}{4}$ ".  
Length of spindle, 52".  
Size of pulley,  $5 \times 5$ ".

SPINDLE, 52" LONG. EITHER  $1\frac{1}{4}$ " OR 1" BETWEEN FLANGES.

This Lathe is designed especially for bicycle manufacturers, although just as good for other classes of metal polishers. Lathes built on similar lines have been on the market for years, but in this machine we have designed new features not found in any other lathe. These improvements are the result of suggestions made by practical polishers, who fully understand what is required in a lathe for this work. A description in detail seems unnecessary, and the lathe must be seen or used to be appreciated.

The boxes in this lathe are the best feature. They are self-lubricating, and can be adjusted in a moment to take up wear. With these boxes it is not necessary to remove the spindle from machine, nor is it necessary to take the boxes off to be planed or rebabbitted. Every practical mechanic will realize the time and annoyance saved by such a device.

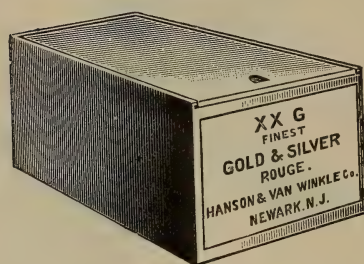
The pulley is made with flanges to prevent belt from slipping against frame when in use on heavy work. Lathe head and column are hollow, enabling them to be belted from the floor below if desired.

The Hanson & Van Winkle Co., Newark, N. J., U. S. A.

---

We manufacture a complete line of 

GRINDING,  
Polishing and Buffing Machines,  
and all the  
Various Wheels and Buffs and Grinding  
and Polishing Material.



FELT

COMPRESS

EMERY

CROCUS

WALRUS

PAPER

VIENNA LIME

CARBORUNDUM

WOOD

SHEEPSKIN

ROUGE

PUMICE

**POLISHING SUPPLIES.**



**TRIPOLI COMPOSITION.**

Tripoli Composition is especially adapted for cutting down and polishing Brass, Bronze, Britannia, and other metals preparatory to plating.

Standard Tripoli Composition, O. S. for cutting and polishing,	per lb.
“ “ “ M, very greasy,	“
“ “ “ No. 6, hard and fast cutting,	“
“ “ “ H, very fast cutting,	“
“ “ “ No. 9, similar to O. S., slightly sharper,	“

**CROCUS COMPOSITION.**

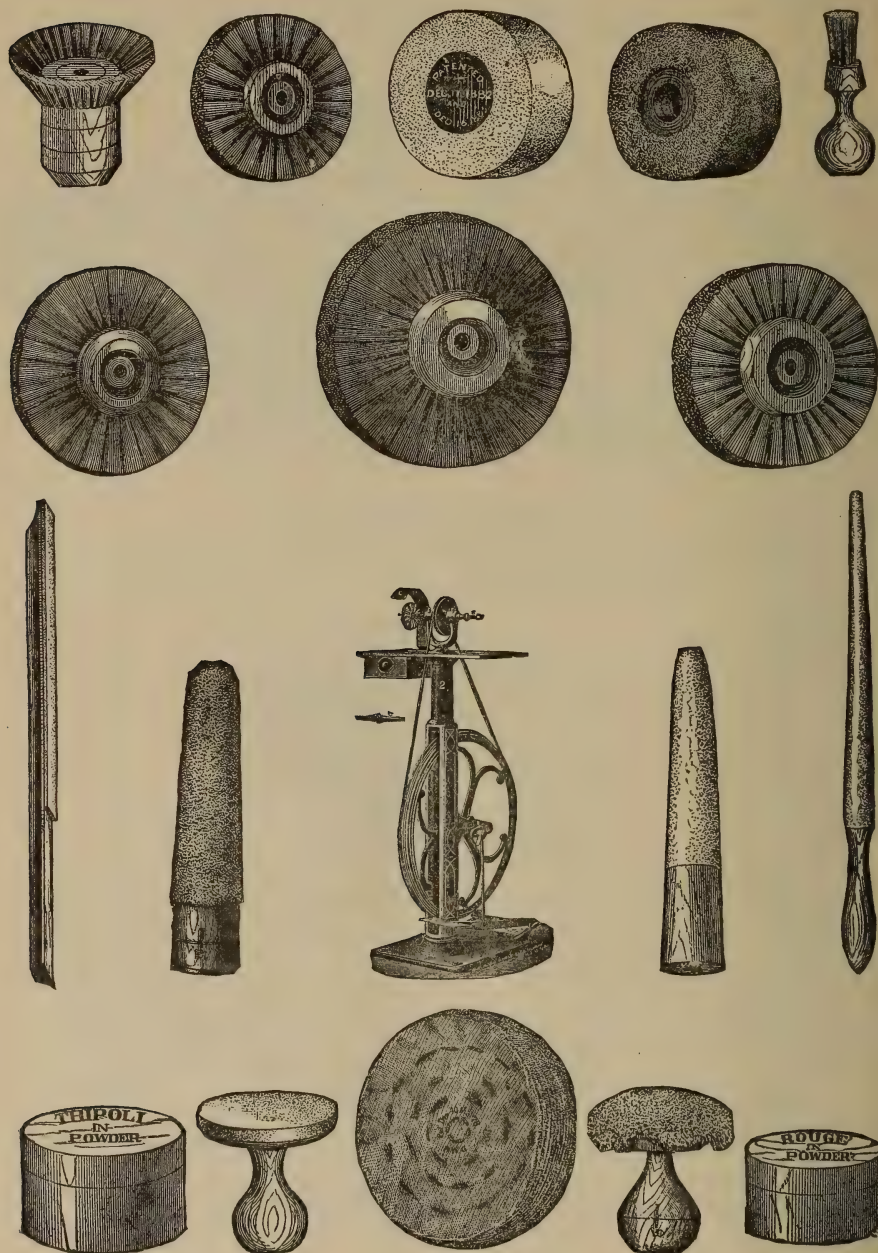
Crocus Composition is largely used by stove manufacturers and others desiring to produce smooth finished surface on cast iron and steel.

A, greasy, fast cutting,	per lb.
F. F., dry and fast cutting,	“
S, dry and fast cutting,	“
O. S., very finest grade of this material,	“
Emery Cake,	“
Emery Paste,	“
English Crocus, powdered, in kegs and casks,	“



The Hanson & Van Winkle Co., Newark, N. J., U. S. A.

POLISHING SET.



No. 200

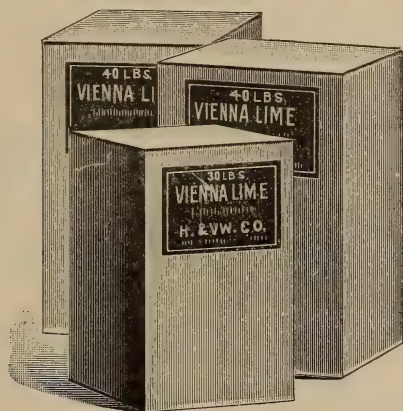
Complete Box of Polishing Tools and Powders for small work . . . \$3.00  
When ordered with No. 22 or 24 Lathe, \$2.00, with samples of Lacquer.

### **XXX BUFFING COMPOUND.**

For polishing and coloring all metals where the higher color is required, with the greatest economy of time, and especially for work that is engraved or ornamented where rouge is objectionable.

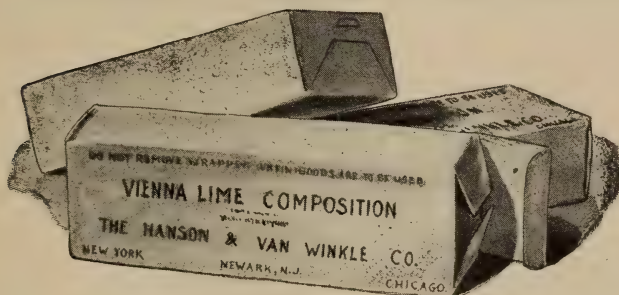
Put up in cakes similar to Tripoli . . . . . per lb.

### **VIENNA LIME.**



We are the largest importers of this article, and furnish it both in lump and powder, and send full instructions for getting best results. There is an increasing demand for this article for nickel and other work, and we are paying special attention to the quality.

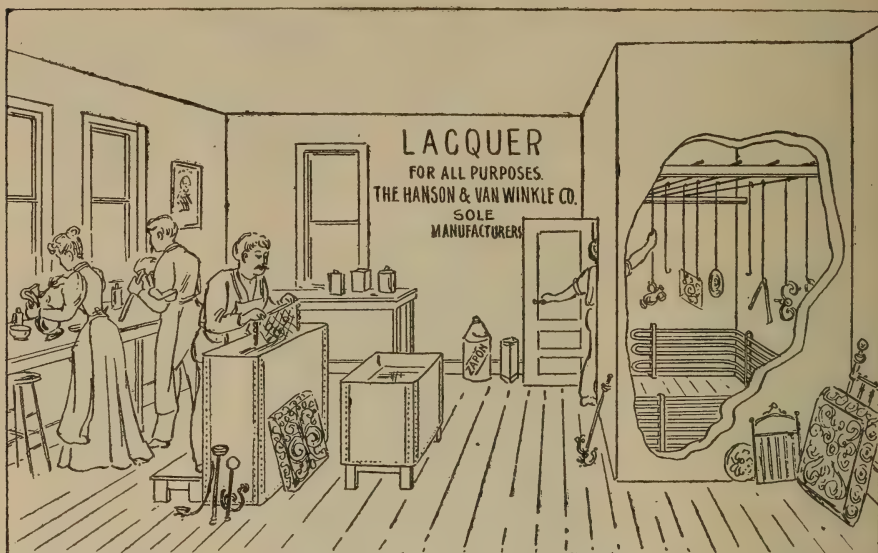
### **VIENNA LIME COMPOSITION.**



This is a very fine coloring material made from uniformly bolted Vienna Lime, and is highly recommended where white results are required.

Put up in square cakes wrapped in paraffined paper, and sealed air-tight.

The Hanson & Van Winkle Co., Newark, N. J., U. S. A.



*Our 184 page Catalogue mailed on application to any address in the world.*

## The Hanson & Van Winkle Co.,

MANUFACTORY AND OFFICES:

219 & 221 MARKET STREET,

Newark, N. J., U. S. A.

NEW YORK OFFICE :

*136 Liberty Street.*

WESTERN BRANCH :

*35 & 37 S. Canal St., Chicago, Ill.*

*13 St. Paul Square, Birmingham, England.*

CATALOGUE  
OF  
Practical and Scientific Books  
PUBLISHED BY  
**HENRY CAREY BAIRD & CO.**

INDUSTRIAL PUBLISHERS, BOOKSELLERS AND IMPORTERS.

**310 Walnut Street, Philadelphia.**

- ☞ Any of the Books comprised in this Catalogue will be sent by mail, free of postage, to any address in the world, at the publication prices.
- ☞ A Descriptive Catalogue, 90 pages, 8vo., will be sent free and free of postage, to any one in any part of the world, who will furnish his address.
- ☞ Where not otherwise stated, all of the Books in this Catalogue are bound in muslin.

---

**AMATEUR MECHANICS' WORKSHOP:**

A treatise containing plain and concise directions for the manipulation of Wood and Metals, including Casting, Forging, Brazing, Soldering and Carpentry. By the author of the "Lathe and Its Uses." Seventh edition. Illustrated. 8vo. . . . \$2.50

**ANDES.—Animal Fats and Oils:**

Their Practical Production, Purification and Uses; their Properties, Falsification and Examination. 62 illustrations. 8vo. . . \$4.00

**ANDES.—Vegetable Fats and Oils:**

Their Practical Preparation, Purification and Employment; their Properties, Adulteration and Examination. 94 illustrations. 8vo. . . \$4.00

**ARLOT.—A Complete Guide for Coach Painters:**

Translated from the French of M. ARLOT, Coach Painter, for eleven years Foreman of Painting to M. Eherler, Coach Maker, Paris. By A. A. FESQUET, Chemist and Engineer. To which is added an Appendix, containing Information respecting the Materials and the Practice of Coach and Car Painting and Varnishing in the United States and Great Britain. 12mo. . . . \$1.25



**ARMENGAUD, AMOROUX, AND JOHNSON.**—The Practical Draughtsman's Book of Industrial Design, and Machinist's and Engineer's Drawing Companion :

Forming a Complete Course of Mechanical Engineering and Architectural Drawing. From the French of M. Armengaud the elder, Prof. of Design in the Conservatoire of Arts and Industry, Paris, and MM. Armengaud the younger, and Amoroux, Civil Engineers. Rewritten and arranged with additional matter and plates, selections from and examples of the most useful and generally employed mechanism of the day. By WILLIAM JOHNSON, Assoc. Inst. C. E. Illustrated by fifty folio steel plates, and fifty wood-cuts. A new edition, 4to., cloth. . . . . \$6.00

**ARMSTRONG.**—The Construction and Management of Steam Boilers :

By R. ARMSTRONG, C. E. With an Appendix by ROBERT MALLET, C. E., F. R. S. Seventh Edition. Illustrated. 1 vol. 12mo. .60

**ARROWSMITH.**—Paper-Hanger's Companion :

A Treatise in which the Practical Operations of the Trade are Systematically laid down: with Copious Directions Preparatory to Papering; Preventives against the Effect of Damp on Walls; the various Cements and Pastes Adapted to the Several Purposes of the Trade; Observations and Directions for the Panelling and Ornamenting of Rooms, etc. By JAMES ARROWSMITH. 12mo., cloth. . . . . \$1.00

**ASHTON.**—The Theory and Practice of the Art of Designing Fancy Cotton and Woollen Cloths from Sample :

Giving full instructions for reducing drafts, as well as the methods of spooling and making out harness for cross drafts and finding any required reed; with calculations and tables of yarn. By FREDERIC T. ASHTON, Designer, West Pittsfield, Mass. With fifty-two illustrations. One vol. folio . . . . . \$5.00

**ASKINSON.**—Perfumes and their Preparation :

A Comprehensive Treatise on Perfumery, containing Complete Directions for Making Handkerchief Perfumes, Smelling-Salts, Sachets, Fumigating Pastils; Preparations for the Care of the Skin, the Mouth, the Hair; Cosmetics, Hair Dyes, and other Toilet Articles. By G.W. ASKINSON. Translated from the German by ISIDOR FURST. Revised by CHARLES RICE. 32 Illustrations. 8vo. \$3.00

**BRONGNIART.**—Coloring and Decoration of Ceramic Ware. 8vo. . . . . \$2.00

**BAIRD.**—The American Cotton Spinner, and Manager's and Carder's Guide:

A Practical Treatise on Cotton Spinning; giving the Dimensions and Speed of Machinery, Draught and Twist Calculations, etc.; with notices of recent Improvements: together with Rules and Examples for making changes in the sizes and numbers of Roving and Yarn. Compiled from the papers of the late ROBERT H. BAIRD. 12mo. . . . . \$1.50

**BAIRD.—Standard Wages Computing Tables:**

An Improvement in all former Methods of Computation, so arranged that wages for days, hours, or fractions of hours, at a specified rate per day or hour, may be ascertained at a glance. By T. SPANGLER BAIRD. Oblong folio . . . . . \$5.00

**BAKER.—Long-Span Railway Bridges:**

Comprising Investigations of the Comparative Theoretical and Practical Advantages of the various Adopted or Proposed Type Systems of Construction; with numerous Formulæ and Tables. By B. BAKER. 12mo. . . . . \$1.00

**BAKER.—The Mathematical Theory of the Steam-Engine:**

With Rules at length, and Examples worked out for the use of Practical Men. By T. BAKER, C. E., with numerous Diagrams. Sixth Edition, Revised by Prof. J. R. YOUNG. 12mo. . . . . 75

**BARLOW.—The History and Principles of Weaving, by Hand and by Power:**

Reprinted, with Considerable Additions, from "Engineering," with a chapter on Lace-making Machinery, reprinted from the Journal of the "Society of Arts." By ALFRED BARLOW. With several hundred illustrations. 8vo., 443 pages . . . . . (Scarce.)

**BARR.—A Practical Treatise on the Combustion of Coal:**

Including descriptions of various mechanical devices for the Economic Generation of Heat by the Combustion of Fuel, whether solid, liquid or gaseous. 8vo. . . . . \$2.50

**BARR.—A Practical Treatise on High Pressure Steam Boilers:**

Including Results of Recent Experimental Tests of Boiler Materials, together with a Description of Approved Safety Apparatus, Steam Pumps, Injectors and Economizers in actual use. By WM. M. BARR. 204 Illustrations. 8vo. . . . . \$3.00

**BAUERMAN.—A Treatise on the Metallurgy of Iron:**

Containing Outlines of the History of Iron Manufacture, Methods of Assay, and Analysis of Iron Ores, Processes of Manufacture of Iron and Steel, etc., etc. By H. BAUERMAN, F. G. S., Associate of the Royal School of Mines. Fifth Edition, Revised and Enlarged. Illustrated with numerous Wood Engravings from Drawings by J. B. JORDAN. 12mo. . . . . \$2.00

**BRANNT.—The Metallic Alloys: A Practical Guide**

For the Manufacture of all kinds of Alloys, Amalgams, and Solders, used by Metal-Workers; together with their Chemical and Physical Properties and their Application in the Arts and the Industries; with an Appendix on the Coloring of Alloys and the Recovery of Waste Metals. By WILLIAM T. BRANNT. 34 Engravings. A New, Revised, and Enlarged Edition. 554 pages. 8vo. . . . . \$4.50

**BEANS.—A Treatise on Railway Curves and Location of Railroads:**

By E. W. BEANS, C. E. Illustrated. 12mo. Tucks . . . . . \$1.50

**BECKETT.—A Rudimentary Treatise on Clocks, and Watches and Bells:**

By Sir EDMUND BECKETT, Bart., LL. D., Q. C. F. R. A. S. With numerous illustrations. Seventh Edition, Revised and Enlarged. 12mo. . . . . \$1.80

**BELL.—Carpentry Made Easy:**

Or, The Science and Art of Framing on a New and Improved System. With Specific Instructions for Building Balloon Frames, Barn Frames, Mill Frames, Warehouses, Church Spires, etc. . . . Comprising also a System of Bridge Building, with Bills, Estimates of Cost, and valuable Tables. Illustrated by forty-four plates, comprising nearly 200 figures. By WILLIAM E. BELL, Architect and Practical Builder. 8vo. . . . \$5.00

**BEMROSE.—Fret-Cutting and Perforated Carving:**

With fifty-three practical illustrations. By W. BEMROSE, JR. 1 vol. quarto . . . \$2.50

**BEMROSE.—Manual of Buhl-work and Marquetry:**

With Practical Instructions for Learners, and ninety colored designs. By W. BEMROSE, JR. 1 vol. quarto . . . \$3.00

**BEMROSE.—Manual of Wood Carving:**

With Practical Illustrations for Learners of the Art, and Original and Selected Designs. By WILLIAM BEMROSE, JR. With an Introduction by LLEWELLYN JEWITT, F. S. A., etc. With 128 illustrations, 4to. . . . \$2.50

**BILLINGS.—Tobacco:**

Its History, Variety, Culture, Manufacture, Commerce, and Various Modes of Use. By E. R. BILLINGS. Illustrated by nearly 200 engravings. 8vo. . . . \$3.00

**BIRD.—The American Practical Dyers' Companion:**

Comprising a Description of the Principal Dye-Stuffs and Chemicals used in Dyeing, their Natures and Uses; Mordants, and How Made; with the best American, English, French and German processes for Bleaching and Dyeing Silk, Wool, Cotton, Linen, Flannel, Felt, Dress Goods, Mixed and Hosiery Yarns, Feathers, Grass, Felt, Fur, Wool, and Straw Hats, Jute Yarn, Vegetable Ivory, Mats, Skins, Furs, Leather, etc., etc. By Wood, Aniline, and other Processes, together with Remarks on Finishing Agents, and Instructions in the Finishing of Fabrics, Substitutes for Indigo, Water-Proofing of Materials, Tests and Purification of Water, Manufacture of Aniline and other New Dye Wares, Harmonizing Colors, etc., etc.; embracing in all over 800 Receipts for Colors and Shades, *accompanied by 170 Dyed Samples of Raw Materials and Fabrics.* By F. J. BIRD, Practical Dyer, Author of "The Dyers' Hand-Book." 8vo. \$7.50

**BLINN.—A Practical Workshop Companion for Tin, Sheet-Iron, and Copper-plate Workers:**

Containing Rules for describing various kinds of Patterns used by Tin, Sheet-Iron and Copper-plate Workers; Practical Geometry; Mensuration of Surfaces and Solids; Tables of the Weights of Metals, Lead-pipe, etc.; Tables of Areas and Circumferences of Circles; Japan, Varnishes, Lackers, Cements, Compositions, etc., etc. By LEROY J. BLINN, Master Mechanic. With One Hundred and Seventy Illustrations. 12mo. . . . \$2.50

**BOOTH.—Marble Worker's Manual:**

Containing Practical Information respecting Marbles in general, their Cutting, Working and Polishing; Veneering of Marble; Mosaics; Composition and Use of Artificial Marble, Stuccos, Cements, Receipts, Secrets, etc., etc. Translated from the French by M. L. BOOTH. With an Appendix concerning American Marbles. 12mo., cloth \$1.50

**BOOTH and MORFIT.—The Encyclopædia of Chemistry, Practical and Theoretical:**

Embracing its application to the Arts, Metallurgy, Mineralogy, Geology, Medicine and Pharmacy. By JAMES C. BOOTH, Melter and Refiner in the United States Mint, Professor of Applied Chemistry in the Franklin Institute, etc., assisted by CAMPBELL MORFIT, author of "Chemical Manipulations," etc. Seventh Edition. Complete in one volume; royal 8vo., 978 pages, with numerous wood-cuts and other illustrations . . . . . (Scarce.)

**BRAMWELL.—The Wool Carder's Vade-Mecum:**

A Complete Manual of the Art of Carding Textile Fabrics. By W. C. BRAMWELL. Third Edition, revised and enlarged. Illustrated. Pp. 400. 12mo. . . . . \$2.50

**BRANNT.—A Practical Treatise on Animal and Vegetable Fats and Oils:**

Comprising both Fixed and Volatile Oils, their Physical and Chemical Properties and Uses, the Manner of Extracting and Refining them, and Practical Rules for Testing them; as well as the Manufacture of Artificial Butter and Lubricants, etc., with lists of American Patents relating to the Extraction, Rendering, Refining, Decomposing, and Bleaching of Fats and Oils. By WILLIAM T. BRANNT, Editor of the "Techno-Chemical Receipt Book." Second Edition, Revised and in a great part Rewritten. Illustrated by 302 Engravings. In Two Volumes. 1304 pp. 8vo. . . . . \$10.00

**BRANNT.—A Practical Treatise on the Manufacture of Soap and Candles:**

Based upon the most Recent Experiences in the Practice and Science; comprising the Chemistry, Raw Materials, Machinery, and Utensils and Various Processes of Manufacture, including a great variety of formulas. Edited chiefly from the German of Dr. C. Deite, A. Engelhardt, Dr. C. Schaedler and others; with additions and lists of American Patents relating to these subjects. By WM. T. BRANNT. Illustrated by 163 engravings. 677 pages. 8vo. . . . . \$7.50

**BRANNT.—India Rubber, Gutta Percha and Balata:**

Occurrence, Geographical Distribution, and Cultivation, Obtaining and Preparing the Raw Materials, Modes of Working and Utilizing them, Including Washing, Maceration, Mixing, Vulcanizing, Rubber and Gutta-Percha Compounds, Utilization of Waste, etc. By WILLIAM T. BRANNT. Illustrated. 12mo. (1900.) . . . . . \$3.00



**BRANNT—WAHL.—The Techno-Chemical Receipt Book:**

Containing several thousand Receipts covering the latest, most important, and most useful discoveries in Chemical Technology, and their Practical Application in the Arts and the Industries. Edited chiefly from the German of Drs. Winckler, Elsner, Heintze, Mierzinski, Jacobsen, Koller, and Heinzerling, with additions by Wm. J. BRANNT and Wm. H. WAHL, PH. D. Illustrated by 78 engravings. 12mo. 495 pages \$2.00

**BROWN.—Five Hundred and Seven Mechanical Movements:**

Embracing all those which are most important in Dynamics, Hydraulics, Hydrostatics, Pneumatics, Steam-Engines, Mill and other Gearing, Presses, Horology and Miscellaneous Machinery; and including many movements never before published, and several of which have only recently come into use. By HENRY T. BROWN 12mo. \$1.00

**BUCKMASTER.—The Elements of Mechanical Physics:**

By J. C. BUCKMASTER. Illustrated with numerous engravings. 12mo. \$1.00

**BULLOCK.—The American Cottage Builder:**

A Series of Designs, Plans and Specifications, from \$200 to \$20,000, for Homes for the People; together with Warming, Ventilation, Drainage, Painting and Landscape Gardening. By JOHN BULLOCK, Architect and Editor of "The Rudiments of Architecture and Building," etc., etc. Illustrated by 75 engravings. 8vo. \$2.50

**BULLOCK.—The Rudiments of Architecture and Building:**

For the use of Architects, Builders, Draughtsmen, Machinists, Engineers and Mechanics. Edited by JOHN BULLOCK, author of "The American Cottage Builder." Illustrated by 250 Engravings. 8vo. \$2.50

**BURGH.—Practical Rules for the Proportions of Modern Engines and Boilers for Land and Marine Purposes.**

By N. P. BURGH, Engineer. 12mo. \$1.50

**BYLES.—Sophisms of Free Trade and Popular Political Economy Examined.**

By a BARRISTER (SIR JOHN BARNARD BYLES, Judge of Common Pleas). From the Ninth English Edition, as published by the Manchester Reciprocity Association. 12mo. \$1.25

**BOWMAN.—The Structure of the Wool Fibre in its Relation to the Use of Wool for Technical Purposes:**

Being the substance, with additions, of Five Lectures, delivered at the request of the Council, to the members of the Bradford Technical College, and the Society of Dyers and Colorists. By F. H. BOWMAN, D.Sc., F.R.S.E., F.L.S. Illustrated by 32 engravings. 8vo. \$5.00

**BYRNE.—Hand-Book for the Artisan, Mechanic, and Engineer:**

Comprising the Grinding and Sharpening of Cutting Tools, Abrasive Processes, Lapidary Work, Gem and Glass Engraving, Varnishing and Lackering, Apparatus, Materials and Processes for Grinding and

Polishing, etc. By OLIVER BYRNE. Illustrated by 185 wood engravings. 8vo. \$5.00

**BYRNE.—Pocket-Book for Railroad and Civil Engineers:**

Containing New, Exact and Concise Methods for Laying out Railroad Curves, Switches, Frog Angles and Crossings; the Staking out of work; Levelling; the Calculation of Cuttings; Embankments; Earth-work, etc. By OLIVER BYRNE. 18mo.; full bound, pocket-book form \$1.50

**BYRNE.—The Practical Metal-Worker's Assistant:**

Comprising Metallurgic Chemistry; the Arts of Working all Metals and Alloys; Forging of Iron and Steel; Hardening and Tempering; Melting and Mixing; Casting and Founding; Works in Sheet Metal; the Processes Dependent on the Ductility of the Metals; Soldering; and the most Improved Processes and Tools employed by Metal-Workers. With the Application of the Art of Electro-Metallurgy to Manufacturing Processes; collected from Original Sources, and from the works of Holtzapffel, Bergeron, Leupold, Plumier, Napier, Scoffern, Clay, Fairbairn and others. By OLIVER BYRNE. A new, revised and improved edition, to which is added an Appendix, containing The Manufacture of Russian Sheet-Iron. By JOHN PERCY, M. D., F. R. S. The Manufacture of Malleable Iron Castings, and Improvements in Bessemer Steel. By A. A. FESQUET, Chemist and Engineer. With over Six Hundred Engravings, illustrating every Branch of the Subject. 8vo. \$5.00

**BYRNE.—The Practical Model Calculator:**

For the Engineer, Mechanic, Manufacturer of Engine Work, Naval Architect, Miner and Millwright. By OLIVER BYRNE. 8vo., nearly 600 pages \$3.00

**CABINET MAKER'S ALBUM OF FURNITURE:**

Comprising a Collection of Designs for various Styles of Furniture. Illustrated by Forty-eight Large and Beautifully Engraved Plates. Oblong, 8vo. \$1.50

**CALLINGHAM.—Sign Writing and Glass Embossing:**

A Complete Practical Illustrated Manual of the Art. By JAMES CALLINGHAM. To which are added Numerous Alphabets and the Art of Letter Painting Made Easy. By JAMES C. BADENOCH. 258 pages. 12mo. \$1.50

**CAMPIN.—A Practical Treatise on Mechanical Engineering:**

Comprising Metallurgy, Moulding, Casting, Forging, Tools, Workshop Machinery, Mechanical Manipulation, Manufacture of Steam-Engines, etc. With an Appendix on the Analysis of Iron and Iron Ores. By FRANCIS CAMPIN, C. E. To which are added, Observations on the Construction of Steam Boilers, and Remarks upon Furnaces used for Smoke Prevention; with a Chapter on Explosions. By R. ARMSTRONG, C. E., and JOHN BOURNE. (Scarce.)

- CAREY.—A Memoir of Henry C. Carey.**  
By DR. WM. ELDER. With a portrait. 8vo., cloth . . . 75
- CAREY.—The Works of Henry C. Carey:**  
**Harmony of Interests: Agricultural, Manufacturing and Commercial.** 8vo. \$1.25  
**Manual of Social Science.** Condensed from Carey's "Principles of Social Science." By KATE MCKEAN. 1 vol. 12mo. . \$2.00  
**Miscellaneous Works.** With a Portrait. 2 vols. 8vo. \$10.00  
**Past, Present and Future.** 8vo. . . \$2.50  
**Principles of Social Science.** 3 volumes, 8vo. . . \$7.50  
**The Slave-Trade, Domestic and Foreign; Why it Exists, and How it may be Extinguished (1853).** 8vo. . . \$2.00  
**The Unity of Law: As Exhibited in the Relations of Physical, Social, Mental and Moral Science (1872).** 8vo. . . \$2.50
- CLARK.—Tramways, their Construction and Working:**  
Embracing a Comprehensive History of the System. With an exhaustive analysis of the various modes of traction, including horse-power, steam, heated water and compressed air; a description of the varieties of Rolling stock, and ample details of cost and working expenses. By D. KINNEAR CLARK. Illustrated by over 200 wood engravings, and thirteen folding plates. 1 vol. 8vo. . \$7.50
- COLBURN.—The Locomotive Engine:**  
Including a Description of its Structure, Rules for Estimating its Capabilities, and Practical Observations on its Construction and Management. By ZERAH COLBURN. Illustrated. 12mo. . \$1.00
- COLLENS.—The Eden of Labor; or, the Christian Utopia.**  
By T. WHARTON COLLENS, author of "Humanics," "The History of Charity," etc. 12mo. Paper cover, \$1.00; Cloth . \$1.25
- COOLEY.—A Complete Practical Treatise on Perfumery:**  
Being a Hand-book of Perfumes, Cosmetics and other Toilet Articles With a Comprehensive Collection of Formulæ. By ARNOLD COOLEY. 12mo. . \$1.50
- COOPER.—A Treatise on the use of Belting for the Transmission of Power.**  
With numerous illustrations of approved and actual methods of arranging Main Driving and Quarter Twist Belts, and of Belt Fastenings. Examples and Rules in great number for exhibiting and calculating the size and driving power of Belts. Plain, Particular and Practical Directions for the Treatment, Care and Management of Belts. Descriptions of many varieties of Beltings, together with chapters on the Transmission of Power by Ropes; by Iron and Wood Frictional Gearing; on the Strength of Belting Leather; and on the Experimental Investigations of Morin, Briggs, and others. By JOHN H. COOPER, M. E. 8vo. . \$3.50
- CRAIK.—The Practical American Millwright and Miller.**  
By DAVID CRAIK, Millwright. Illustrated by numerous wood engravings and two folding plates. 8vo. . . (Scarce.)

**CROSS.—The Cotton Yarn Spinner :**

Showing how the Preparation should be arranged for Different Counts of Yarns by a System more uniform than has hitherto been practiced; by having a Standard Schedule from which we make all our Changes. By RICHARD CROSS. 122 pp. 12mo. . . 75

**CRISTIANI.—A Technical Treatise on Soap and Candles :**

With a Glance at the Industry of Fats and Oils. By R. S. CRISTIANI, Chemist. Author of "Perfumery and Kindred Arts." Illustrated by 176 engravings. 581 pages, 8vo. \$15.00

**COURTNEY.—The Boiler Maker's Assistant in Drawing, Templating, and Calculating Boiler Work and Tank Work, etc.**

Revised by D. K. CLARK. 102 ills. Fifth edition. . . 80

**COURTNEY.—The Boiler Maker's Ready Reckoner :**

With Examples of Practical Geometry and Templating. Revised by D. K. CLARK, C. E. 37 illustrations. Fifth edition. . \$1.60

**DAVIDSON.—A Practical Manual of House Painting, Grain-ing, Marbling, and Sign-Writing :**

Containing full information on the processes of House Painting in Oil and Distemper, the Formation of Letters and Practice of Sign-Writing, the Principles of Decorative Art, a Course of Elementary Drawing for House Painters, Writers, etc., and a Collection of Useful Receipts. With nine colored illustrations of Woods and Marbles, and numerous wood engravings. By ELLIS A. DAVIDSON. 12mo. \$2.00

**DAVIES.—A Treatise on Earthy and Other Minerals and Mining :**

By D. C. DAVIES, F. G. S., Mining Engineer, etc. Illustrated by 76 Engravings. 12mo. . . \$5.00

**DAVIES.—A Treatise on Metalliferous Minerals and Mining :**

By D. C. DAVIES, F. G. S., Mining Engineer, Examiner of Mines, Quarries and Collieries. Illustrated by 148 engravings of Geological Formations, Mining Operations and Machinery, drawn from the practice of all parts of the world. Fifth Edition, thoroughly Revised and much Enlarged by his son, E. Henry Davies. 12mo., 524 pages . . . \$5.00

**DAVIES.—A Treatise on Slate and Slate Quarrying :**

Scientific, Practical and Commercial. By D. C. DAVIES, F. G. S., Mining Engineer, etc. With numerous illustrations and folding plates. 12mo. . . \$1.20

**DAVIS.—A Practical Treatise on the Manufacture of Brick, Tiles and Terra-Cotta :**

Including Stiff Clay, Dry Clay, Hand Made, Pressed or Front, and Roadway Paving Brick, Enamelled Brick, with Glazes and Colors, Fire Brick and Blocks, Silica Brick, Carbon Brick, Glass Pots, Re-



torts, Architectural Terra-Cotta, Sewer Pipe, Drain Tile, Glazed and Unglazed Roofing Tile, Art Tile, Mosaics, and Imitation of Intarsia or Inlaid Surfaces. Comprising every product of Clay employed in Architecture, Engineering, and the Blast Furnace. With a Detailed Description of the Different Clays employed, the Most Modern Machinery, Tools, and Kilns used, and the Processes for Handling, Disintegrating, Tempering, and Moulding the Clay into Shape, Drying, Setting, and Burning. By Charles Thomas Davis. Third Edition. Revised and in great part rewritten. Illustrated by 261 engravings. 662 pages . . . . . \$5.00

**DAVIS.—A Treatise on Steam-Boiler Incrustation and Methods for Preventing Corrosion and the Formation of Scale:**  
By CHARLES T. DAVIS. Illustrated by 65 engravings. 8vo. \$2.00

**DAVIS.—The Manufacture of Paper:**  
Being a Description of the various Processes for the Fabrication, Coloring and Finishing of every kind of Paper, Including the Different Raw Materials and the Methods for Determining their Values, the Tools, Machines and Practical Details connected with an intelligent and a profitable prosecution of the art, with special reference to the best American Practice. To which are added a History of Paper, complete Lists of Paper-Making Materials, List of American Machines, Tools and Processes used in treating the Raw Materials, and in Making, Coloring and Finishing Paper. By CHARLES T. DAVIS. Illustrated by 156 engravings. 608 pages, 8vo. \$6.00

**DAVIS.—The Manufacture of Leather:**  
Being a Description of all the Processes for the Tanning and Tawing with Bark, Extracts, Chrome and all Modern Tannages in General Use, and the Currying, Finishing and Dyeing of Every Kind of Leather; Including the Various Raw Materials, the Tools, Machines, and all Details of Importance Connected with an Intelligent and Profitable Prosecution of the Art, with Special Reference to the Best American Practice. To which are added Lists of American Patents (1884-1897) for Materials, Processes, Tools and Machines for Tanning, Currying, etc. By CHARLES THOMAS DAVIS. Second Edition, Revised, and in great part Rewritten. Illustrated by 147 engravings and 14 Samples of Quebracho Tanned and Aniline Dyed Leathers. 8vo, cloth, 712 pages. Price . . . . . \$7.50

**DAWIDOWSKY—BRANNT.—A Practical Treatise on the Raw Materials and Fabrication of Glue, Gelatine, Gelatine Veneers and Foils, Isinglass, Cements, Pastes, Mucilages, etc.:**

Based upon Actual Experience. By F. DAWIDOWSKY, Technical Chemist. Translated from the German, with extensive additions, including a description of the most Recent American Processes, by WILLIAM T. BRANNT, Graduate of the Royal Agricultural College of Eldena, Prussia. 35 Engravings. 12mo. . . . . \$2.50

**DE GRAFF.—The Geometrical Stair-Builders' Guide:**  
Being a Plain Practical System of Hand-Railing, embracing all its necessary Details, and Geometrically Illustrated by twenty-two Steel Engravings; together with the use of the most approved principles of Practical Geometry. By SIMON DE GRAFF, Architect. (Scarce.)

**DE KONINCK—DIETZ.—A Practical Manual of Chemical Analysis and Assaying:**

As applied to the Manufacture of Iron from its Ores, and to Cast Iron, Wrought Iron, and Steel, as found in Commerce. By L. L. DE KONINCK, Dr. Sc., and E. DIETZ, Engineer. Edited with Notes, by ROBERT MALLET, F. R. S., F. S. G., M. I. C. E., etc. American Edition, Edited with Notes and an Appendix on Iron Ores, by A. A. FESQUET, Chemist and Engineer. 12mo. . . . \$1.50

**DUNCAN.—Practical Surveyor's Guide:**

Containing the necessary information to make any person of common capacity, a finished land surveyor without the aid of a teacher. By ANDREW DUNCAN. Revised. 72 engravings, 214 pp. 12mo. \$1.50

**DUPLAIS.—A Treatise on the Manufacture and Distillation of Alcoholic Liquors:**

Comprising Accurate and Complete Details in Regard to Alcohol from Wine, Molasses, Beets, Grain, Rice, Potatoes, Sorghum, Asphodel, Fruits, etc.; with the Distillation and Rectification of Brandy, Whiskey, Rum, Gin, Swiss Absinthe, etc., the Preparation of Aromatic Waters, Volatile Oils or Essences, Sugars, Syrups, Aromatic Tinctures, Liqueurs, Cordial Wines, Effervescing Wines, etc., the Ageing of Brandy and the improvement of Spirits, with Copious Directions and Tables for Testing and Reducing Spirituous Liquors, etc., etc. Translated and Edited from the French of MM. DUPLAIS, By M. McKENNIE, M. D. Illustrated. 743 pp. 8vo. \$15.00

**DYER AND COLOR-MAKER'S COMPANION:**

Containing upwards of two hundred Receipts for making Colors, on the most approved principles, for all the various styles and fabrics now in existence; with the Scouring Process, and plain Directions for Preparing, Washing-off, and Finishing the Goods. 12mo. \$1.00

**EIDHERR.—The Techno-Chemical Guide to Distillation:**

A Hand-Book for the Manufacture of Alcohol and Alcoholic Liquors, including the Preparation of Malt and Compressed Yeast. Edited from the German of Ed. Eidherr. Fully illustrated. (In preparation.)

**EDWARDS.—A Catechism of the Marine Steam-Engine,**

For the use of Engineers, Firemen, and Mechanics. A Practical Work for Practical Men. By EMORY EDWARDS, Mechanical Engineer. Illustrated by sixty-three Engravings, including examples of the most modern Engines. Third edition, thoroughly revised, with much additional matter. 12mo. 414 pages . . . \$2.00

**EDWARDS.—Modern American Locomotive Engines,**

Their Design, Construction and Management. By EMORY EDWARDS. Illustrated 12mo. . . . \$2.00

**EDWARDS.—The American Steam Engineer:**

Theoretical and Practical, with examples of the latest and most approved American practice in the design and construction of Steam Engines and Boilers. For the use of engineers, machinists, boiler-makers, and engineering students. By EMORY EDWARDS. Fully illustrated, 419 pages. 12mo. . . . \$2.50

**EDWARDS.—Modern American Marine Engines, Boilers, and Screw Propellers,**

Their Design and Construction. Showing the Present Practice of the most Eminent Engineers and Marine Engine Builders in the United States. Illustrated by 30 large and elaborate plates. 4to. \$5.00

**EDWARDS.—The Practical Steam Engineer's Guide**

In the Design, Construction, and Management of American Stationary, Portable, and Steam Fire-Engines, Steam Pumps, Boilers, Injectors, Governors, Indicators, Pistons and Rings, Safety Valves and Steam Gauges. For the use of Engineers, Firemen, and Steam Users. By EMORY EDWARDS. Illustrated by 119 engravings. 420 pages. 12mo. \$2 50

**EISSLER.—The Metallurgy of Gold :**

A Practical Treatise on the Metallurgical Treatment of Gold-Bearing Ores, including the Processes of Concentration and Chlorination, and the Assaying, Melting, and Refining of Gold. By M. EISSLER. With 132 Illustrations. 12mo. \$7.50

**EISSLER.—The Metallurgy of Silver :**

A Practical Treatise on the Amalgamation, Roasting, and Lixiviation of Silver Ores, including the Assaying, Melting, and Refining of Silver Bullion. By M. EISSLER. 124 Illustrations. 336 pp. 12mo. \$4.25

**ELDER.—Conversations on the Principal Subjects of Political Economy.**

By DR. WILLIAM ELDER. 8vo. \$2.50

**ELDER.—Questions of the Day,**

Economic and Social. By DR. WILLIAM ELDER. 8vo. \$3.00

**ERNI AND BROWN.—Mineralogy Simplified.**

Easy Methods of Identifying Minerals, including Ores, by Means of the Blow-pipe, by Flame Reactions, by Humid Chemical Analysis, and by Physical Tests. By HENRI ERNI, A. M., M. D. Third Edition, revised, re-arranged and with the addition of entirely new matter, including Tables for the Determination of Minerals by Chemical and Pyrognostic Characters, and by Physical Characters. By AMOS P. BROWN, E. M., Ph. D. 350 pp., illustrated by 96 engravings, pocket-book form, full flexible morocco, gilt edges \$2.50

**FAIRBAIRN.—The Principles of Mechanism and Machinery of Transmission**

Comprising the Principles of Mechanism, Wheels, and Pulleys, Strength and Proportions of Shafts, Coupling of Shafts, and Engaging and Disengaging Gear. By SIR WILLIAM FAIRBAIRN, Bart. C. E. Beautifully illustrated by over 150 wood-cuts. In one volume, 12mo. \$2.00

**FLEMING.—Narrow Gauge Railways in America.**

A Sketch of their Rise, Progress, and Success. Valuable Statistics as to Grades, Curves, Weight of Rail, Locomotives, Cars, etc. By HOWARD FLEMING. Illustrated, 8vo. \$1 00

**FORSYTH.—Book of Designs for Headstones, Mural, and other Monuments :**

Containing 78 Designs. By JAMES FORSYTH. With an Introduction by CHARLES BOUTELL, M. A. 4 to., cloth \$3.50

**FRANKEL—HUTTER.—A Practical Treatise on the Manufacture of Starch, Glucose, Starch-Sugar, and Dextrine:**

Based on the German of LADISLAUS VON WAGNER, Professor in the Royal Technical High School, Buda-Pest, Hungary, and other authorities. By JULIUS FRANKEL, Graduate of the Polytechnic School of Hanover. Edited by ROBERT HUTTER, Chemist, Practical Manufacturer of Starch-Sugar. Illustrated by 58 engravings, covering every branch of the subject, including examples of the most Recent and Best American Machinery. 8vo., 344 pp. . . \$3.50

**GARDNER.—The Painter's Encyclopædia:**

Containing Definitions of all Important Words in the Art of Plain and Artistic Painting, with Details of Practice in Coach, Carriage, Railway Car, House, Sign, and Ornamental Painting, including Graining, Marbling, Staining, Varnishing, Polishing, Lettering, Stenciling, Gilding, Bronzing, etc. By FRANKLIN B. GARDNER. 158 Illustrations. 12mo. 427 pp. . . . \$2.00

**GARDNER.—Everybody's Paint Book:**

A Complete Guide to the Art of Outdoor and Indoor Painting. 38 illustrations. 12mo, 183 pp. . . . \$1.00

**GEE.—The Jeweller's Assistant in the Art of Working in Gold:**

A Practical Treatise for Masters and Workmen. 12mo. . . \$3.00

**GEE.—The Goldsmith's Handbook:**

Containing full instructions for the Alloying and Working of Gold, including the Art of Alloying, Melting, Reducing, Coloring, Collecting, and Refining; the Processes of Manipulation, Recovery of Waste; Chemical and Physical Properties of Gold; with a New System of Mixing its Alloys; Solders, Enamels, and other Useful Rules and Recipes. By GEORGE E. GEE. 12mo. . . . \$1.25

**GEE.—The Silversmith's Handbook:**

Containing full instructions for the Alloying and Working of Silver, including the different modes of Refining and Melting the Metal; its Solders; the Preparation of Imitation Alloys; Methods of Manipulation; Prevention of Waste; Instructions for Improving and Finishing the Surface of the Work; together with other Useful Information and Memoranda. By GEORGE E. GEE. Illustrated. 12mo. . . \$1.25

**GOTHIC ALBUM FOR CABINET-MAKERS:**

Designs for Gothic Furniture. Twenty-three plates. Oblong \$1.50

**GRANT.—A Handbook on the Teeth of Gears:**

Their Curves, Properties, and Practical Construction. By GEORGE B. GRANT. Illustrated. Third Edition, enlarged. 8vo. . . \$1.00

**GREENWOOD.—Steel and Iron:**

Comprising the Practice and Theory of the Several Methods Pursued in their Manufacture, and of their Treatment in the Rolling-Mills, the Forge, and the Foundry. By WILLIAM HENRY GREENWOOD, F. C. S. With 97 Diagrams, 536 pages. 12mo. . . \$1.75



**GREGORY.—Mathematics for Practical Men:**

Adapted to the Pursuits of Surveyors, Architects, Mechanics, and Civil Engineers. By OLINTHUS GREGORY. 8vo., plates \$3.00

**GRISWOLD.—Railroad Engineer's Pocket Companion for the Field:**

Comprising Rules for Calculating Deflection Distances and Angles, Tangential Distances and Angles, and all Necessary Tables for Engineers; also the Art of Levelling from Preliminary Survey to the Construction of Railroads, intended Expressly for the Young Engineer, together with Numerous Valuable Rules and Examples. By W. GRISWOLD. 12mo., tucks . . . . . \$1.50

**GRUNER.—Studies of Blast Furnace Phenomena:**

By M. L. GRUNER, President of the General Council of Mines of France, and lately Professor of Metallurgy at the Ecole des Mines. Translated, with the author's sanction, with an Appendix, by L. D. B. GORDON, F. R. S. E., F. G. S. 8vo. . . . . \$2.50

**Hand-Book of Useful Tables for the Lumberman, Farmer and Mechanic:**

Containing Accurate Tables of Logs Reduced to Inch Board Measure, Plank, Scantling and Timber Measure; Wages and Rent, by Week or Month; Capacity of Granaries, Bins and Cisterns; Land Measure, Interest Tables, with Directions for Finding the Interest on any sum at 4, 5, 6, 7 and 8 per cent., and many other Useful Tables. 32 mo., boards. 186 pages . . . . . .25

**HASERICK.—The Secrets of the Art of Dyeing Wool, Cotton, and Linen,**

Including Bleaching and Coloring Wool and Cotton Hosiery and Random Yarns. A Treatise based on Economy and Practice. By E. C. HASERICK. *Illustrated by 323 Dyed Patterns of the Yarns or Fabrics.* 8vo. . . . . \$5.00

**HATS AND FELTING:**

A Practical Treatise on their Manufacture. By a Practical Hatter. Illustrated by Drawings of Machinery, etc. 8vo. . . . \$1.25

**HERMANN.—Painting on Glass and Porcelain, and Enamel Painting:**

A Complete Introduction to the Preparation of all the Colors and Fluxes Used for Painting on Glass, Porcelain, Enamel, Faience and Stoneware, the Color Pastes and Colored Glasses, together with a Minute Description of the Firing of Colors and Enamels, on the Basis of Personal Practical Experience of the Art up to Date. 18 illustrations. Second edition. . . . . \$4.00

**HAUPT.—Street Railway Motors:**

With Descriptions and Cost of Plants and Operation of the Various Systems now in Use. 12mo., . . . . . \$1.75

**HAUPT.—A Manual of Engineering Specifications and Contracts.**

By LEWIS M. HAUPT, C. E. Illustrated with numerous maps.  
328pp. 8vo. . . . . \$3 00

**HAUPT.—The Topographer, His Instruments and Methods.**

By LEWIS M. HAUPT, A. M., C. E. Illustrated with numerous  
plates, maps and engravings. 247 pp. 8vo. . . . . \$3.00

**HUGHES.—American Miller and Millwright's Assistant:**

By WILLIAM CARTER HUGHES. 12mo. . . . . \$1.50

**HULME.—Worked Examination Questions in Plane Geometrical Drawing:**

For the Use of Candidates for the Royal Military Academy, Woolwich; the Royal Military College, Sandhurst; the Indian Civil Engineering College, Cooper's Hill; Indian Public Works and Telegraph Departments; Royal Marine Light Infantry; the Oxford and Cambridge Local Examinations, etc. By F. EDWARD HULME, F. L. S., F. S. A., Art-Master Marlborough College. Illustrated by 300 examples. Small quarto . . . . . \$1.50

**JERVIS.—Railroad Property:**

A Treatise on the Construction and Management of Railways; designed to afford useful knowledge, in the popular style, to the holders of this class of property; as well as Railway Managers, Officers, and Agents. By JOHN B. JERVIS, late Civil Engineer of the Hudson River Railroad, Croton Aqueduct, etc. 12mo., cloth \$2.00

**KEENE.—A Hand-Book of Practical Gauging:**

For the Use of Beginners, to which is added a Chapter on Distillation, describing the process in operation at the Custom-House for ascertaining the Strength of Wines. By JAMES B. KEENE, of H. M. Customs. 8vo. . . . . \$1 00

**KELLEY.—Speeches, Addresses, and Letters on Industrial and Financial Questions:**

By HON. WILLIAM D. KELLEY, M. C. 544 pages, 8vo. . . . . \$2.50

**KELLOGG.—A New Monetary System:**

The only means of Securing the respective Rights of Labor and Property, and of Protecting the Public from Financial Revulsions. By EDWARD KELLOGG. 12mo. Paper cover, \$1.00. Bound in cloth. . . . . \$1.25

**KEMLO.—Watch-Repairer's Hand-Book:**

Being a Complete Guide to the Young Beginner, in Taking Apart Putting Together, and Thoroughly Cleaning the English Lever and other Foreign Watches, and all American Watches. By F. KEMLO, Practical Watchmaker. With Illustrations. 12mo. . . . . \$1.25

- KENTISH.**—*A Treatise on a Box of Instruments, And the Slide Rule; with the Theory of Trigonometry and Logarithms, including Practical Geometry, Surveying, Measuring of Timber, Cask and Malt Gauging, Heights, and Distances.* By THOMAS KENTISH. In one volume. 12mo. . . . \$1.00
- KERL.**—*The Assayer's Manual:*  
An Abridged Treatise on the Docimastic Examination of Ores, and Furnace and other Artificial Products. By BRUNO KERL, Professor in the Royal School of Mines. Translated from the German by WILLIAM T. BRANNT. Second American edition, edited with Extensive Additions by F. LYNWOOD GARRISON, Member of the American Institute of Mining Engineers, etc. Illustrated by 87 engravings. 8vo. (Scarce.)
- KICK.**—*Flour Manufacture.*  
A Treatise on Milling Science and Practice. By FREDERICK KICK Imperial Regierungsrath, Professor of Mechanical Technology in the Imperial German Polytechnic Institute, Prague. Translated from the second enlarged and revised edition with supplement by H. H. P. POWLES, Assoc. Memb. Institution of Civil Engineers. Illustrated with 28 Plates, and 167 Wood-cuts. 367 pages. 8vo. . \$10.00
- KINGZETT.**—*The History, Products, and Processes of the Alkali Trade:*  
Including the most Recent Improvements. By CHARLES THOMAS KINGZETT, Consulting Chemist. With 23 illustrations. 8vo. \$2.50
- KIRK.**—*The Cupola Furnace:*  
A Practical Treatise on the Construction and Management of Foundry Cupolas. By EDWARD KIRK, Practical Moulder and Melter, Consulting Expert in Melting. Author of "The Founding of Metals." Illustrated by 78 engravings. 8vo. 379 pages. . \$3.50
- LANDRIN.**—*A Treatise on Steel:*  
Comprising its Theory, Metallurgy, Properties, Practical Working, and Use. By M. H. C. LANDRIN, JR. From the French, by A. A. FESQUET. 12mo. . . . \$2.50
- LANGBEIN.**—*A Complete Treatise on the Electro-Deposition of Metals:*  
Comprising Electro-Plating and Galvanoplastic Operations, the Deposition of Metals by the Contact and Immersion Processes, the Coloring of Metals, the Methods of Grinding and Polishing, as well as Descriptions of the Electric Elements, Dynamo-Electric Machines, Thermo-Piles and of the Materials and Processes used in Every Department of the Art. From the German of DR. GEORGE LANGBEIN, with additions by WM. T. BRANNT. Fourth Edition, thoroughly revised and much enlarged. 150 Engravings. 550 pages. 8vo. 1902. \$4.00
- LARDNER.**—*The Steam-Engine:*  
For the Use of Beginners. Illustrated. 12mo. . . . .60
- LEHNER.**—*The Manufacture of Ink:*  
Comprising the Raw Materials, and the Preparation of Writing, Copying and Hektograph Inks, Safety Inks, Ink Extracts and Powders, etc. Translated from the German of SIGMUND LEHNER, with additions by WILLIAM T. BRANNT. Illustrated. 12mo. \$2.00

**LARKIN.—The Practical Brass and Iron Founder's Guide:**

A Concise Treatise on Brass Founding, Moulding, the Metals and their Alloys, etc.; to which are added Recent Improvements in the Manufacture of Iron, Steel by the Bessemer Process, etc., etc. By JAMES LARKIN, late Conductor of the Brass Foundry Department in Reany, Neafie & Co.'s Penn Works, Philadelphia. New edition, revised, with extensive additions. 414 pages. 12mo. . . \$2.50

**LEROUX.—A Practical Treatise on the Manufacture of Worsted and Carded Yarns:**

Comprising Practical Mechanics, with Rules and Calculations applied to Spinning; Sorting, Cleaning, and Scouring Wools; the English and French Methods of Combing; Drawing, and Spinning Worsted, and Manufacturing Carded Yarns. Translated from the French of CHARLES LEROUX, Mechanical Engineer and Superintendent of a Spinning-Mill, by HORATIO PAINE, M. D., and A. A. FESQUET, Chemist and Engineer. Illustrated by twelve large Plates. To which is added an Appendix, containing Extracts from the Reports of the International Jury, and of the Artisans selected by the Committee appointed by the Council of the Society of Arts, London, on Woollen and Worsted Machinery and Fabrics, as exhibited in the Paris Universal Exposition, 1867. 8vo. . . . \$5.00

**LEFFEL.—The Construction of Mill-Dams:**

Comprising also the Building of Race and Reservoir Embankments and Head-Gates, the Measurement of Streams, Gauging of Water Supply, etc. By JAMES LEFFEL & Co. Illustrated by 58 engravings. 8vo. . . . \$2.50

**LESLIE.—Complete Cookery:**

Directions for Cookery in its Various Branches. By MISS LESLIE. Sixtieth thousand. Thoroughly revised, with the addition of New Receipts. 12mo. . . . \$1.50

**LE VAN.—The Steam Engine and the Indicator:**

Their Origin and Progressive Development; including the Most Recent Examples of Steam and Gas Motors, together with the Indicator, its Principles, its Utility, and its Application. By WILLIAM BARNET LE VAN. Illustrated by 205 Engravings, chiefly of Indicator-Cards. 469 pp. 8vo. . . . \$4.00

**LIEBER.—Assayer's Guide:**

Or, Practical Directions to Assayers, Miners, and Smelters, for the Tests and Assays, by Heat and by Wet Processes, for the Ores of all the principal Metals, of Gold and Silver Coins and Alloys, and of Coal, etc. By OSCAR M. LIEBER. Revised. 283 pp. 12mo. . \$1.50

**Lockwood's Dictionary of Terms:**

Used in the Practice of Mechanical Engineering, embracing those Current in the Drawing Office, Pattern Shop, Foundry, Fitting, Turning, Smith's and Boiler Shops, etc., etc., comprising upwards of Six Thousand Definitions. Edited by a Foreman Pattern Maker, author of "Pattern Making." 417 pp. 12mo. . . . \$3.00



**LUKIN.—The Lathe and Its Uses :**

Or Instruction in the Art of Turning Wood and Metal. Including a Description of the Most Modern Appliances for the Ornamentation of Plane and Curved Surfaces, an Entirely Novel Form of Lathe for Eccentric and Rose-Engine Turning; A Lathe and Planing Machine Combined; and Other Valuable Matter Relating to the Art. Illustrated by 462 engravings. Seventh edition. 315 pages. 8vo. . . . . \$4.25

**MAIN and BROWN.—Questions on Subjects Connected with the Marine Steam-Engine :**

And Examination Papers; with Hints for their Solution. By THOMAS J. MAIN, Professor of Mathematics, Royal Naval College, and THOMAS BROWN, Chief Engineer, R. N. 12mo., cloth . . \$1.00

**MAIN and BROWN.—The Indicator and Dynamometer :**

With their Practical Applications to the Steam-Engine. By THOMAS J. MAIN, M. A. F. R., Ass't S. Professor Royal Naval College, Portsmouth, and THOMAS BROWN, Assoc. Inst. C. E., Chief Engineer R. N., attached to the R. N. College. Illustrated. 8vo. .

**MAIN and BROWN.—The Marine Steam-Engine.**

By THOMAS J. MAIN, F. R. Ass't S. Mathematical Professor at the Royal Naval College, Portsmouth, and THOMAS BROWN, Assoc. Inst. C. E., Chief Engineer R. N. Attached to the Royal Naval College. With numerous illustrations. 8vo. . . . .

**MAKINS.—A Manual of Metallurgy :**

By GEORGE HOGARTH MAKINS. 100 engravings. Second edition rewritten and much enlarged. 12mo., 592 pages . . . \$3.00

**MARTIN.—Screw-Cutting Tables, for the Use of Mechanical Engineers :**

Showing the Proper Arrangement of Wheels for Cutting the Threads of Screws of any Required Pitch; with a Table for Making the Universal Gas-Pipe Thread and Taps. By W. A. MARTIN, Engineer. 8vo. . . . . .50

**MICHELL.—Mine Drainage :**

Being a Complete and Practical Treatise on Direct-Acting Underground Steam Pumping Machinery. With a Description of a large number of the best known Engines, their General Utility and the Special Sphere of their Action, the Mode of their Application, and their Merits compared with other Pumping Machinery. By STEPHEN MICHELL. Illustrated by 247 engravings. 8vo., 369 pages. \$12 50

**MOLESWORTH.—Pocket-Book of Useful Formulæ and Memoranda for Civil and Mechanical Engineers.**

By GUILFORD L. MOLESWORTH, Member of the Institution of Civil Engineers, Chief Resident Engineer of the Ceylon Railway. Full-bound in Pocket-book form . . . . . \$1.00

**MOORE.—The Universal Assistant and the Complete Mechanic:**

Containing over one million Industrial Facts, Calculations, Receipts, Processes, Trades Secrets, Rules, Business Forms, Legal Items, Etc., in every occupation, from the Household to the Manufactory. By R. MOORE. Illustrated by 500 Engravings. 12mo. . . . \$2.50

**MORRIS.—Easy Rules for the Measurement of Earthworks:**

By means of the Prismoidal Formula. Illustrated with Numerous Wood-Cuts, Problems, and Examples, and concluded by an Extensive Table for finding the Solidity in cubic yards from Mean Areas, The whole being adapted for convenient use by Engineers, Surveyors, Contractors, and others needing Correct Measurements of Earthwork. By ELWOOD MORRIS, C. E. 8vo. . . . \$1.50

**MAUCHLINE.—The Mine Foreman's Hand-Book**

Of Practical and Theoretical Information on the Opening, Ventilating, and Working of Collieries. Questions and Answers on Practical and Theoretical Coal Mining. Designed to Assist Students and Others in Passing Examinations for Mine Foremanships. By ROBERT MAUCHLINE, Ex-Inspector of Mines. A New, Revised and Enlarged Edition. Illustrated by 114 engravings. 8vo. 337 pages . . . \$3.75

**NAPIER.—A System of Chemistry Applied to Dyeing.**

By JAMES NAPIER, F. C. S. A New and Thoroughly Revised Edition. Completely brought up to the present state of the Science, including the Chemistry of Coal Tar Colors, by A. A. FESQUET, Chemist and Engineer. With an Appendix on Dyeing and Calico Printing, as shown at the Universal Exposition, Paris, 1867. Illustrated. 8vo. 422 pages . . . \$3.00

**NEVILLE.—Hydraulic Tables, Coefficients, and Formulæ, for finding the Discharge of Water from Orifices, Notches, Weirs, Pipes, and Rivers:**

Third Edition, with Additions, consisting of New Formulæ for the Discharge from Tidal and Flood Sluices and Siphons; general information on Rainfall, Catchment-Basins, Drainage, Sewerage, Water Supply for Towns and Mill Power. By JOHN NEVILLE, C. E. M. R. I. A.; Fellow of the Royal Geological Society of Ireland. Thick 12mo. . . . \$5.50

**NEWBERRY.—Gleanings from Ornamental Art of every style:**

Drawn from Examples in the British, South Kensington, Indian, Crystal Palace, and other Museums, the Exhibitions of 1851 and 1862, and the best English and Foreign works. In a series of 100 exquisitely drawn Plates, containing many hundred examples. By ROBERT NEWBERRY. 4to. . . . (Scarce.)

**NICHOLLS.—The Theoretical and Practical Boiler-Maker and Engineer's Reference Book:**

Containing a variety of Useful Information for Employers of Labor Foremen and Working Boiler-Makers. Iron, Copper, and Tinsmiths

- Draughtsmen, Engineers, the General Steam-using Public, and for the Use of Science Schools and Classes.** By SAMUEL NICHOLLS. Illustrated by sixteen plates, 12mo. \$2.50
- NICHOLSON.—A Manual of the Art of Bookbinding:**  
Containing full instructions in the different Branches of Forwarding, Gilding, and Finishing. Also, the Art of Marbling Book-edges and Paper. By JAMES B. NICHOLSON. Illustrated, 12mo., cloth \$2.25
- NICOLLS.—The Railway Builder:**  
A Hand-Book for Estimating the Probable Cost of American Railway Construction and Equipment. By WILLIAM J. NICOLLS, Civil Engineer. Illustrated, full bound, pocket-book form \$2.00
- NORMANDY.—The Commercial Handbook of Chemical Analysis:**  
Or Practical Instructions for the Determination of the Intrinsic or Commercial Value of Substances used in Manufactures, in Trades, and in the Arts. By A. NORMANDY. New Edition, Enlarged, and to a great extent rewritten. By HENRY M. NOAD, Ph.D., F.R.S., thick 12mo. \$5.00
- NORRIS.—A Handbook for Locomotive Engineers and Machinists:**  
Comprising the Proportions and Calculations for Constructing Locomotives; Manner of Setting Valves; Tables of Squares, Cubes, Areas, etc., etc. By SEPTIMUS NORRIS, M. E. New edition. Illustrated, 12mo. \$1.50
- NYSTROM.—A New Treatise on Elements of Mechanics:**  
Establishing Strict Precision in the Meaning of Dynamical Terms; accompanied with an Appendix on Duodenal Arithmetic and Metrology. By JOHN W. NYSTROM, C. E. Illustrated. 8vo. \$3.00
- NYSTROM.—On Technological Education and the Construction of Ships and Screw Propellers:**  
For Naval and Marine Engineers. By JOHN W. NYSTROM, late Acting Chief Engineer, U. S. N. Second edition, revised, with additional matter. Illustrated by seven engravings. 12mo. \$1.25
- O'NEILL.—A Dictionary of Dyeing and Calico Printing:**  
Containing a brief account of all the Substances and Processes in use in the Art of Dyeing and Printing Textile Fabrics; with Practical Receipts and Scientific Information. By CHARLES O'NEILL, Analytical Chemist. To which is added an Essay on Coal Tar Colors and their application to Dyeing and Calico Printing. By A. A. FESQUET, Chemist and Engineer. With an appendix on Dyeing and Calico Printing, as shown at the Universal Exposition, Paris, 1867. 8vo., 491 pages \$3.00
- ORTON.—Underground Treasures:**  
How and Where to Find Them. A Key for the Ready Determination of all the Useful Minerals within the United States. By JAMES ORTON, A.M., Late Professor of Natural History in Vassar College, N. Y.; author of the "Andes and the Amazon," etc. A New Edition, with An Appendix on Ore Deposits and Testing Minerals (1901). Illustrated \$1.50

**OSBORN.—The Prospector's Field Book and Guide.**

In the Search For and the Easy Determination of Ores and Other Useful Minerals. By Prof. H. S. OSBORN, LL. D. Illustrated by 58 Engravings. 12mo. Fifth Edition. Revised and Enlarged (1901) . . . . . \$1.50

**OSBORN.—A Practical Manual of Minerals, Mines and Mining:**

Comprising the Physical Properties, Geologic Positions, Local Occurrence and Associations of the Useful Minerals; their Methods of Chemical Analysis and Assay; together with Various Systems of Excavating and Timbering, Brick and Masonry Work, during Driving, Lining, Bracing and other Operations, etc. By Prof. H. S. OSBORN, LL. D., Author of "The Prospector's Field-Book and Guide," 171 engravings. Second Edition, revised. 8vo. . . . . \$4.50

**OVERMAN.—The Manufacture of Steel:**

Containing the Practice and Principles of Working and Making Steel. A Handbook for Blacksmiths and Workers in Steel and Iron, Wagon Makers, Die Sinkers, Cutlers, and Manufacturers of Files and Hardware, of Steel and Iron, and for Men of Science and Art. By FREDERICK OVERMAN, Mining Engineer, Author of the "Manufacture of Iron," etc. A new, enlarged, and revised Edition. By A. A. FESQUET, Chemist and Engineer. 12mo. . . . . \$1.50

**OVERMAN.—The Moulder's and Founder's Pocket Guide:**

A Treatise on Moulding and Founding in Green-sand, Dry-sand, Loam, and Cement; the Moulding of Machine Frames, Mill-gear, Hollowware, Ornaments, Trinkets, Bells, and Statues; Description of Moulds for Iron, Bronze, Brass, and other Metals; Plaster of Paris, Sulphur, Wax, etc.; the Construction of Melting Furnaces, the Melting and Founding of Metals; the Composition of Alloys and their Nature, etc., etc. By FREDERICK OVERMAN, M. E. A new Edition, to which is added a Supplement on Statuary and Ornamental Moulding, Ordnance, Malleable Iron Castings, etc. By A. A. FESQUET, Chemist and Engineer. Illustrated by 44 engravings. 12mo. . . . . \$2.00

**PAINTER, GILDER, AND VARNISHER'S COMPANION.**

Comprising the Manufacture and Test of Pigments, the Arts of Painting, Graining, Marbling, Staining, Sign-writing, Varnishing, Glass-staining, and Gilding on Glass; together with Coach Painting and Varnishing, and the Principles of the Harmony and Contrast of Colors. Twenty-seventh Edition. Revised, Enlarged, and in great part Rewritten. By WILLIAM T. BRANNT, Editor of "Varnishes, Lacquers, Printing Inks and Sealing Waxes." Illustrated. 395 pp. 12mo. . . . . \$1.50

**PALLET.—The Miller's, Millwright's, and Engineer's Guide.**

By HENRY PALLET. Illustrated. 12mo. . . . . \$2.00



**PERCY.—The Manufacture of Russian Sheet-Iron.**

By JOHN PERCY, M. D., F. R. S. Paper. . . . . 25 cts.

**PERKINS.—Gas and Ventilation:**

Practical Treatise on Gas and Ventilation. Illustrated. 12mo. \$1.25

**PERKINS AND STOWE.—A New Guide to the Sheet-iron and Boiler Plate Roller:**

Containing a Series of Tables showing the Weight of Slabs and Piles to Produce Boiler Plates, and of the Weight of Piles and the Sizes of Bars to produce Sheet-iron; the Thickness of the Bar Gauge in decimals; the Weight per foot, and the Thickness on the Bar or Wire Gauge of the fractional parts of an inch; the Weight per sheet, and the Thickness on the Wire Gauge of Sheet-iron of various dimensions to weigh 112 lbs. per bundle; and the conversion of Short Weight into Long Weight, and Long Weight into Short.

\$1.50

**POSSELT.—Recent Improvements in Textile Machinery Relating to Weaving:**

Giving the Most Modern Points on the Construction of all Kinds of Looms, Warpings, Beamers, Slashers, Winders, Spoolers, Reeds, Temples, Shuttles, Bobbins, Heddles, Heddle Frames, Pickers, Jacquards, Card Stampers, etc., etc. 600 illus. . . . \$3.00

**POSSELT.—Technology of Textile Design:**

The Most Complete Treatise on the Construction and Application of Weaves for all Textile Fabrics and the Analysis of Cloth. By E. A. Possett. 1,500 illustrations. 4to. . . . \$5.00

**POSSELT.—Textile Calculations:**

A Guide to Calculations Relating to the Manufacture of all Kinds of Yarns and Fabrics, the Analysis of Cloth, Speed, Power and Belt Calculations. By E. A. POSSELT. Illustrated. 4to. . . \$2.00

**REGNAULT.—Elements of Chemistry:**

By M. V. REGNAULT. Translated from the French by T. FORREST BETTON, M. D., and edited, with Notes, by JAMES C. BOOTH, Melter and Refiner U. S. Mint, and WILLIAM L. FABER, Metallurgist and Mining Engineer. Illustrated by nearly 700 wood-engravings. Comprising nearly 1,500 pages. In two volumes, 8vo., cloth . . \$6.00

**RICHARDS.—Aluminium:**

Its History, Occurrence, Properties, Metallurgy and Applications, including its Alloys. By JOSEPH W. RICHARDS, A. C., Chemist and Practical Metallurgist, Member of the Deutsche Chemische Gesellschaft. Illust. Third edition, enlarged and revised (1895) . \$6.00

**RIFFAULT, VERGNAUD, and TOUSSAINT.—A Practical****Treatise on the Manufacture of Colors for Painting:**

Comprising the Origin, Definition, and Classification of Colors; the Treatment of the Raw Materials; the best Formulæ and the Newest Processes for the Preparation of every description of Pigment, and the Necessary Apparatus and Directions for its Use; Dryers; the Testing, Application, and Qualities of Paints, etc., etc. By MM. RIFFAULT, VERGNAUD, and TOUSSAINT. Revised and Edited by M.

F. MALEPEYRE. Translated from the French, by A. A. FESQUEL, Chemist and Engineer. Illustrated by Eighty engravings. In one vol., 8vo., 659 pages . . . \$5.00

**ROPER.—A Catechism of High-Pressure, or Non-Condensing Steam-Engines :**

Including the Modelling, Constructing, and Management of Steam-Engines and Steam Boilers. With valuable illustrations. By STEPHEN ROPER, Engineer. Sixteenth edition, revised and enlarged. 18mo., tucks, gilt edge . . . \$2.00

**I ROPER.—Engineer's Handy-Book :**

Containing a full Explanation of the Steam-Engine Indicator, and its Use and Advantages to Engineers and Steam Users. With Formulæ for Estimating the Power of all Classes of Steam-Engines; also, Facts, Figures, Questions, and Tables for Engineers who wish to qualify themselves for the United States Navy, the Revenue Service, the Mercantile Marine, or to take charge of the Better Class of Stationary Steam-Engines. Tenth edition. 16mo., 690 pages, tucks, gilt edge . . . \$3.50

**ROPER.—Hand-Book of Land and Marine Engines :**

Including the Modelling, Construction, Running, and Management of Land and Marine Engines and Boilers. With illustrations. By STEPHEN ROPER, Engineer. Sixth edition. 12mo., tucks, gilt edge. \$3.50

**ROPER.—Hand-Book of the Locomotive :**

Including the Construction of Engines and Boilers, and the Construction, Management, and Running of Locomotives. By STEPHEN ROPER. Eleventh edition. 18mo., tucks, gilt edge . . . \$2.50

**ROPER.—Hand-Book of Modern Steam Fire-Engines.**

With illustrations. By STEPHEN ROPER, Engineer. Fourth edition, 12mo., tucks, gilt edge . . . \$3.50

**ROPER.—Questions and Answers for Engineers.**

This little book contains all the Questions that Engineers will be asked when undergoing an Examination for the purpose of procuring Licenses, and they are so plain that any Engineer or Fireman of ordinary intelligence may commit them to memory in a short time. By STEPHEN ROPER, Engineer. Third edition . . . \$2.00

**ROPER.—Use and Abuse of the Steam Boiler.**

By STEPHEN ROPER, Engineer. Eighth edition, with illustrations. 18mo., tucks, gilt edge . . . \$2.00

**ROSE.—The Complete Practical Machinist :**

Embracing Lathe Work, Vise Work, Drills and Drilling, Taps and Dies, Hardening and Tempering, the Making and Use of Tools Tool Grinding, Marking out Work, Machine Tools, etc. By JOSHUA ROSE. 395 Engravings. Nineteenth Edition, greatly Enlarged with New and Valuable Matter. 12mo., 504 pages. . . \$2.50

**ROSE.—Mechanical Drawing Self-Taught :**

Comprising Instructions in the Selection and Preparation of Drawing Instruments, Elementary Instruction in Practical Mechanical Draw-

- ing, together with Examples in Simple Geometry and Elementary Mechanism, including Screw Threads, Gear Wheels, Mechanical Motions, Engines and Boilers. By JOSHUA ROSE, M. E. Illustrated by 330 engravings. 8vo, 313 pages . . . \$4.00
- ROSE.—The Slide-Valve Practically Explained:**  
Embracing simple and complete Practical Demonstrations of the operation of each element in a Slide-valve Movement, and illustrating the effects of Variations in their Proportions by examples carefully selected from the most recent and successful practice. By JOSHUA ROSE, M. E. Illustrated by 35 engravings . . . \$1.00
- ROSS.—The Blowpipe in Chemistry, Mineralogy and Geology:**  
Containing all Known Methods of Anhydrous Analysis, many Working Examples, and Instructions for Making Apparatus. By LIEUT.-COLONEL W. A. ROSS, R. A., F. G. S. With 120 Illustrations. 12mo. . . . . \$2.00
- SHAW.—Civil Architecture:**  
Being a Complete Theoretical and Practical System of Building, containing the Fundamental Principles of the Art. By EDWARD SHAW, Architect. To which is added a Treatise on Gothic Architecture, etc. By THOMAS W. SILLOWAY and GEORGE M. HARDING, Architects. The whole illustrated by 102 quarto plates finely engraved on copper. Eleventh edition. 4to. . . . . \$6.00
- SHUNK.—A Practical Treatise on Railway Curves and Location, for Young Engineers.**  
By W. F. SHUNK, C. E. 12mo. Full bound pocket-book form \$2.00
- SLATER.—The Manual of Colors and Dye Wares.**  
By J. W. SLATER. 12mo. . . . . \$3.00
- SLOAN.—American Houses:**  
A variety of Original Designs for Rural Buildings. Illustrated by 26 colored engravings, with descriptive references. By SAMUEL SLOAN, Architect. 8vo. . . . . .75
- SLOAN.—Homestead Architecture:**  
Containing Forty Designs for Villas, Cottages, and Farm-houses, with Essays on Style, Construction, Landscape Gardening, Furniture, etc., etc. Illustrated by upwards of 200 engravings. By SAMUEL SLOAN, Architect. 8vo. . . . . \$2 50
- SLOANE.—Home Experiments in Science.**  
By T. O'CONOR SLOANE, E. M., A. M., F. R. S. Illustrated by 91 engravings. 12mo. . . . . \$1.00
- SMEATON.—Builder's Pocket-Companion:**  
Containing the Elements of Building, Surveying, and Architecture; with Practical Rules and Instructions connected with the subject. By A. C. SMEATON, Civil Engineer, etc. 12mo. . . . .
- SMITH.—A Manual of Political Economy.**  
By E. PESHINE SMITH. A New Edition, to which is added a full Index. 12mo. . . . . \$1 25

**SMITH.—Parks and Pleasure-Grounds :**

Or Practical Notes on Country Residences, Villas, Public Parks, and Gardens. By CHARLES H. J. SMITH, Landscape Gardener and Garden Architect, etc., etc. 12mo. . . . . \$2.00

**SMITH.—The Dyer's Instructor :**

Comprising Practical Instructions in the Art of Dyeing Silk, Cotton, Wool, and Worsted, and Woolen Goods; containing nearly 800 Receipts. To which is added a Treatise on the Art of Padding; and the Printing of Silk Warps, Skeins, and Handkerchiefs, and the various Mordants and Colors for the different styles of such work. By DAVID SMITH, Pattern Dyer. 12mo. . . . . \$1.50

**SMYTH.—A Rudimentary Treatise on Coal and Coal-Mining.**

By WARRINGTON W. SMYTH, M. A., F. R. G., President R. G. S. of Cornwall. Fifth edition, revised and corrected. With numerous illustrations. 12mo. . . . . \$1.75

**SNIVELY.—Tables for Systematic Qualitative Chemical Analysis.**

By JOHN H. SNIVELY, Phr. D. 8vo. . . . . \$1.00

**SNIVELY.—The Elements of Systematic Qualitative Chemical Analysis :**

A Hand-book for Beginners. By JOHN H. SNIVELY, Phr. D. 16mo. . . . . \$2.00

**STOKES.—The Cabinet-Maker and Upholsterer's Companion :**

Comprising the Art of Drawing, as applicable to Cabinet Work; Veneering, Inlaying, and Buhl-Work; the Art of Dyeing and Staining Wood, Ivory, Bone, Tortoise-Shell, etc. Directions for Lacking, Japanning, and Varnishing; to make French Polish, Glues, Cements, and Compositions; with numerous Receipts, useful to workmen generally. By STOKES. Illustrated. A New Edition, with an Appendix upon French Polishing, Staining, Imitating, Varnishing, etc., etc. 12mo . . . . . \$1.25

**STRENGTH AND OTHER PROPERTIES OF METALS:**

Reports of Experiments on the Strength and other Properties of Metals for Cannon. With a Description of the Machines for Testing Metals, and of the Classification of Cannon in service. By Officers of the Ordnance Department, U. S. Army. By authority of the Secretary of War. Illustrated by 25 large steel plates. Quarto . . . \$5.00

**SULLIVAN.—Protection to Native Industry.**

By Sir EDWARD SULLIVAN, Baronet, author of "Ten Chapters on Social Reforms." 8vo. . . . . \$1.00

**SHERRATT.—The Elements of Hand-Railing :**

Simplified and Explained in Concise Problems that are Easily Understood. The whole illustrated with Thirty-eight Accurate and Original Plates, Founded on Geometrical Principles, and Showing how to Make Rail Without Centre Joints, Making Better Rail of the Same Material, with Half the Labor, and Showing How to Lay Out Stairs of all Kinds. By R. J. SHERRATT. Folio. . . . . \$2.50



**SYME.—Outlines of an Industrial Science.**

By DAVID SYME. 12mo. \$2.00

**TABLES SHOWING THE WEIGHT OF ROUND, SQUARE, AND FLAT BAR IRON, STEEL, ETC.,**

By Measurement. Cloth 63

**TAYLOR.—Statistics of Coal:**

Including Mineral Bituminous Substances employed in Arts and Manufactures; with their Geographical, Geological, and Commercial Distribution and Amount of Production and Consumption on the American Continent. With Incidental Statistics of the Iron Manufacture. By R. C. TAYLOR. Second edition, revised by S. S. HALDEMAN. Illustrated by five Maps and many wood engravings. 8vo., cloth \$6.00

**TEMPLETON.—The Practical Examiner on Steam and the Steam-Engine:**

With Instructive References relative thereto, arranged for the Use of Engineers, Students, and others. By WILLIAM TEMPLETON, Engineer. 12mo. \$1.00

**THAUSING.—The Theory and Practice of the Preparation of Malt and the Fabrication of Beer:**

With especial reference to the Vienna Process of Brewing. Elaborated from personal experience by JULIUS E. THAUSING, Professor at the School for Brewers, and at the Agricultural Institute, Mödling, near Vienna. Translated from the German by WILLIAM T. BRANNT, Thoroughly and elaborately edited, with much American matter, and according to the latest and most Scientific Practice, by A. SCHWARZ and DR. A. H. BAUER. Illustrated by 140 Engravings. 8vo., 815 pages \$10.00

**THOMPSON.—Political Economy. With Especial Reference to the Industrial History of Nations:**

By ROBERT E. THOMPSON, M. A., Professor of Social Science in the University of Pennsylvania. 12mo. \$1.50

**THOMSON.—Freight Charges Calculator:**

By ANDREW THOMSON, Freight Agent. 24mo. \$1.25

**TURNER'S (THE) COMPANION:**

Containing Instructions in Concentric, Elliptic, and Eccentric Turning; also various Plates of Chucks, Tools, and Instruments; and Directions for using the Eccentric Cutter, Drill, Vertical Cutter, and Circular Rest; with Patterns and Instructions for working them. 12mo. \$1.00

**TURNING: Specimens of Fancy Turning Executed on the Hand or Foot-Lathe:**

With Geometric, Oval, and Eccentric Chucks, and Elliptical Cutting Frame. By an Amateur. Illustrated by 30 exquisite Photographs. 4to. \$2.50

**VAILE.—Galvanized-Iron Cornice-Worker's Manual:**

Containing Instructions in Laying out the Different Mitres, and Making Patterns for all kinds of Plain and Circular Work. Also, Tables of Weights, Areas and Circumferences of Circles, and other Matter calculated to Benefit the Trade. By CHARLES A. VAILE. Illustrated by twenty-one plates. 4to. . . . . \$5.00

**VILLE.—On Artificial Manures:**

Their Chemical Selection and Scientific Application to Agriculture. A series of Lectures given at the Experimental Farm at Vincennes, during 1867 and 1874-75. By M. GEORGES VILLE. Translated and Edited by WILLIAM CROOKES, F. R. S. Illustrated by thirty-one engravings. 8vo., 450 pages . . . . . \$6.00

**VILLE.—The School of Chemical Manures:**

Or, Elementary Principles in the Use of Fertilizing Agents. From the French of M. GEO. VILLE, by A. A. FESQUET, Chemist and Engineer. With Illustrations. 12mo. . . . . \$1.25

**VOGDEN.—The Architect's and Builder's Pocket-Companion and Price-Book:**

Consisting of a Short but Comprehensive Epitome of Decimals, Duodecimals, Geometry and Mensuration; with Tables of United States Measures, Sizes, Weights, Strengths, etc., of Iron, Wood, Stone, Brick, Cement and Concretes, Quantities of Materials in given Sizes and Dimensions of Wood, Brick and Stone; and full and complete Bills of Prices for Carpenter's Work and Painting; also, Rules for Computing and Valuing Brick and Brick Work, Stone Work, Painting, Plastering, with a Vocabulary of Technical Terms, etc. By FRANK W. VOGDEN, Architect, Indianapolis, Ind. Enlarged, revised, and corrected. In one volume, 368 pages, full-bound, pocket-book form, gilt edges . . . . . \$2.00  
Cloth . . . . . 1.50

**VAN CLEVE.—The English and American Mechanic:**

Comprising a Collection of Over Three Thousand Receipts, Rules, and Tables, designed for the Use of every Mechanic and Manufacturer. By B. FRANK VAN CLEVE. Illustrated. 500 pp. 12mo. \$2.00

**WAHNSCHAFTE.—A Guide to the Scientific Examination of Soils:**

Comprising Select Methods of Mechanical and Chemical Analysis and Physical Investigation. Translated from the German of Dr. F. WAHNSCHAFTE. With additions by WILLIAM T. BRANNT. Illustrated by 25 engravings. 12mo. 177 pages . . . . . \$1.50

**WALL.—Practical Graining:**

With Descriptions of Colors Employed and Tools Used. Illustrated by 47 Colored Plates, Representing the Various Woods Used in Interior Finishing. By WILLIAM E. WALL. 8vo. (Scarce.)

**WALTON.—Coal-Mining Described and Illustrated:**

By THOMAS H. WALTON, Mining Engineer. Illustrated by 24 large and elaborate Plates, after Actual Workings and Apparatus. \$5.00

**WARE.—The Sugar Beet.**

Including a History of the Beet Sugar Industry in Europe, Varieties of the Sugar Beet, Examination, Soils, Tillage, Seeds and Sowing, Yield and Cost of Cultivation, Harvesting, Transportation, Conservation, Feeding Qualities of the Beet and of the Pulp, etc. By LEWIS S. WARE, C. E., M. E. Illustrated by ninety engravings. 8vo. \$4.00

**WARN.—The Sheet-Metal Worker's Instructor:**

For Zinc, Sheet-Iron, Copper, and Tin-Plate Workers, etc. Containing a selection of Geometrical Problems; also, Practical and Simple Rules for Describing the various Patterns required in the different branches of the above Trades. By REUBEN H. WARN, Practical Tin-Plate Worker. To which is added an Appendix, containing Instructions for Boiler-Making, Mensuration of Surfaces and Solids, Rules for Calculating the Weights of different Figures of Iron and Steel, Tables of the Weights of Iron, Steel, etc. Illustrated by thirty-two Plates and thirty-seven Wood Engravings. 8vo. \$3.00

**WARNER.—New Theorems, Tables, and Diagrams, for the Computation of Earth-work:**

Designed for the use of Engineers in Preliminary and Final Estimates of Students in Engineering, and of Contractors and other non-professional Computers. In two parts, with an Appendix. Part I. A Practical Treatise; Part II. A Theoretical Treatise, and the Appendix. Containing Notes to the Rules and Examples of Part I.; Explanations of the Construction of Scales, Tables, and Diagrams, and a Treatise upon Equivalent Square Bases and Equivalent Level Heights. By JOHN WARNER, A. M., Mining and Mechanical Engineer. Illustrated by 14 Plates. 8vo. \$3.00

**WILSON.—Carpentry and Joinery:**

By JOHN WILSON, Lecturer on Building Construction, Carpentry and Joinery, etc., in the Manchester Technical School. Third Edition, with 65 full page plates, in flexible cover, oblong .80

**WATSON.—A Manual of the Hand-Lathe:**

Comprising Concise Directions for Working Metals of all kinds, Ivory, Bone and Precious Woods; Dyeing, Coloring, and French Polishing; Inlaying by Veneers, and various methods practised to produce Elaborate work with Dispatch, and at Small Expense. By EGBERT P. WATSON, Author of "The Modern Practice of American Machinists and Engineers." Illustrated by 78 engravings. \$1.50

**WATSON.—The Modern Practice of American Machinists and Engineers**

Including the Construction, Application, and Use of Drills, Lathe Tools, Cutters for Boring Cylinders, and Hollow-work generally, with the most Economical Speed for the same; the Results verified by Actual Practice at the Lathe, the Vise, and on the Floor. Together

- with Workshop Management, Economy of Manufacture, the Steam Engine, Boilers, Gears, Belting, etc., etc. By **EGBERT P. WATSON**. Illustrated by eighty-six engravings. 12mo. . . . \$2.50
- WATT.—The Art of Soap Making :**  
A Practical Hand-Book of the Manufacture of Hard and Soft Soaps, Toilet Soaps, etc. Fifth Edition, Revised, to which is added an Appendix on Modern Candle Making. By **ALEXANDER WATT**. Ill. 12mo. . . . \$3.00
- WEATHERLY.—Treatise on the Art of Boiling Sugar, Crystallizing, Lozenge-making, Comfits, Gum Goods,**  
And other processes for Confectionery, etc., in which are explained, in an easy and familiar manner, the various Methods of Manufacturing every Description of Raw and Refined Sugar Goods, as sold by Confectioners and others. 12mo. . . . \$1.50
- WILL.—Tables of Qualitative Chemical Analysis :**  
With an Introductory Chapter on the Course of Analysis. By Professor **HEINRICH WILL**, of Giessen, Germany. Third American, from the eleventh German edition. Edited by **CHARLES F. HIMES**, Ph. D., Professor of Natural Science, Dickinson College, Carlisle, Pa. 8vo. . . . \$1.50
- WILLIAMS.—On Heat and Steam :**  
Embracing New Views of Vaporization, Condensation and Explosion. By **CHARLES WYE WILLIAMS**, A. I. C. E. Illustrated. 8vo. . . . \$2.50
- WILSON.—First Principles of Political Economy :**  
With Reference to Statesmanship and the Progress of Civilization. By Professor **W. D. WILSON**, of the Cornell University. A new and revised edition. 12mo. . . . \$1.50
- WILSON.—The Practical Tool-Maker and Designer :**  
A Treatise upon the Designing of Tools and Fixtures for Machine Tools and Metal Working Machinery, Comprising Modern Examples of Machines with Fundamental Designs for Tools for the Actual Production of the work; Together with Special Reference to a Set of Tools for Machining the Various Parts of a Bicycle. Illustrated by 189 engravings. 1898. . . . \$2.50
- CONTENTS:** Introductory. Chapter I. Modern Tool Room and Equipment. II. Files, Their Use and Abuse. III. Steel and Tempering. IV. Making Jigs. V. Milling Machine Fixtures. VI. Tools and Fixtures for Screw Machines. VII. Broaching. VIII. Punches and Dies for Cutting and Drop Press. IX. Tools for Hollow-Ware. X. Embossing; Metal, Coin, and Stamped Sheet-Metal Ornaments. XI. Drop Forging. XII. Solid Drawn Shells or Ferrules; Cupping or Cutting, and Drawing; Breaking Down Shells. XIII. Annealing, Pickling and Cleaning. XIV. Tools for Draw Bench. XV. Cutting and Assembling Pieces by Means of Ratchet Dial Plates at One Operation. XVI. The Header. XVII. Tools for Fox Lathe. XVIII. Suggestions for a Set of Tools for Machining the Various Parts of a Bicycle. XIX. The Plater's Dynamo. XX. Conclusion—With a Few Random Ideas. Appendix. Index.
- WOODS.—Compound Locomotives :**  
By **ARTHUR TANNATT WOODS**. Second edition, revised and enlarged by **DAVID LEONARD BARNES**, A. M., C. E. 8vo. 330 pp. \$3.00



**WOHLER.—A Hand-Book of Mineral Analysis :**

By F. WÖHLER, Professor of Chemistry in the University of Göttingen. Edited by HENRY B. NASON, Professor of Chemistry in the Rensselaer Polytechnic Institute, Troy, New York. Illustrated. 12mo.

**WORSSAM.—On Mechanical Saws :**

From the Transactions of the Society of Engineers, 1869. By S. W. WORSSAM, JR. Illustrated by eighteen large plates. 8vo. \$1.50

**RECENT ADDITIONS.**

**BRANNT.—Varnishes, Lacquers, Printing Inks and Sealing-Waxes :**

Their Raw Materials and their Manufacture, to which is added the Art of Varnishing and Lacquering, including the Preparation of Putties and of Stains for Wood, Ivory, Bone, Horn, and Leather. By WILLIAM T. BRANNT. Illustrated by 39 Engravings, 338 pages. 12mo. \$3.00

**BRANNT.—The Practical Scourer and Garment Dyer :**

Comprising Dry or Chemical Cleaning; the Art of Removing Stains; Fine Washing; Bleaching and Dyeing of Straw Hats, Gloves, and Feathers of all kinds; Dyeing of Worn Clothes of all fabrics, including Mixed Goods, by One Dip; and the Manufacture of Soaps and Fluids for Cleansing Purposes. Edited by WILLIAM T. BRANNT, Editor of "The Techno-Chemical Receipt Book." Illustrated. 203 pages. 12mo. \$2.00

**BRANNT.—Petroleum.**

its History, Origin, Occurrence, Production, Physical and Chemical Constitution, Technology, Examination and Uses; Together with the Occurrence and Uses of Natural Gas. Edited chiefly from the German of Prof. Hans Hoefer and Dr. Alexander Veith, by WM. T. BRANNT. Illustrated by 3 Plates and 284 Engravings. 743 pp. 8vo. \$7.50

**BRANNT.—A Practical Treatise on the Manufacture of Vinegar and Acetates, Cider, and Fruit-Wines :**

Preservation of Fruits and Vegetables by Canning and Evaporation; Preparation of Fruit-Butters, Jellies, Marmalades, Catchups, Pickles, Mustards, etc. Edited from various sources. By WILLIAM T. BRANNT. Illustrated by 79 Engravings. 479 pp. 8vo. \$6.00

**BRANNT.—The Metal Worker's Handy-Book of Receipts and Processes :**

Being a Collection of Chemical Formulas and Practical Manipulations for the working of all Metals; including the Decoration and Beautifying of Articles Manufactured therefrom, as well as their Preservation. Edited from various sources. By WILLIAM T. BRANNT. Illustrated. 12mo. \$2.50

**DEITE.—A Practical Treatise on the Manufacture of Perfumery.**

Comprising directions for making all kinds of Perfumes, Sachet Powders, Fumigating Materials, Dentifrices, Cosmetics, etc., with a full account of the Volatile Oils, Balsams, Resins, and other Natural and Artificial Perfume-substances, including the Manufacture of Fruit Ethers, and tests of their purity. By Dr. C. DEITE, assisted by L. BORCHERT, F. EICHBAUM, E. KUGLER, H. TOEFFNER, and other experts. From the German, by WM. T. BRANNT. 28 Engravings. 358 pages. 8vo. . . . . \$3.00

**EDWARDS.—American Marine Engineer, Theoretical and Practical:**

With Examples of the latest and most approved American Practice. By EMORY EDWARDS. 85 illustrations. 12mo. . . . . \$2.50

**EDWARDS.—900 Examination Questions and Answers:**

For Engineers and Firemen (Land and Marine) who desire to obtain a United States Government or State License. Pocket-book form, gilt edge . . . . . \$1.50

**KIRK.—The Cupola Furnace:**

A Practical Treatise on the Construction and Management of Foundry Cupolas. By EDWARD KIRK, Practical Moulder and Melter, author of "The Founding of Metals." Illustrated by 80 Engravings. 8vo. (1899) . . . . . \$3.50

**POSSELT.—The Jacquard Machine Analysed and Explained:**

With an Appendix on the Preparation of Jacquard Cards, and Practical Hints to Learners of Jacquard Designing. By E. A. POSSELT. With 230 illustrations and numerous diagrams. 127 pp. 4to. . . . . \$3.00

**POSSELT.—The Structure of Fibres, Yarns and Fabrics:**

Being a Practical Treatise for the Use of all Persons Employed in the Manufacture of Textile Fabrics, containing a Description of the Growth and Manipulation of Cotton, Wool, Worsted, Silk, Flax, Jute, Ramie, China Grass and Hemp, and Dealing with all Manufacturers' Calculations for Every Class of Material, also Giving Minute Details for the Structure of all kinds of Textile Fabrics, and an Appendix of Arithmetic, specially adapted for Textile Purposes. By E. A. POSSELT. Over 400 Illustrations. quarto. . . . . \$5.00

**RICH.—Artistic Horse-Shoeing:**

A Practical and Scientific Treatise, giving Improved Methods of Shoeing, with Special Directions for Shaping Shoes to Cure Different Diseases of the Foot, and for the Correction of Faulty Action in Trotters. By GEORGE E. RICH. 62 Illustrations. 153 pages. 12mo . . . . . \$1.00

**RICHARDSON.—Practical Blacksmithing:**

A Collection of Articles Contributed at Different Times by Skilled Workmen to the columns of "The Blacksmith and Wheelwright," and Covering nearly the Whole Range of Blacksmithing, from the Simplest Job of Work to some of the Most Complex Forgings. Compiled and Edited by M. T. RICHARDSON.

Vol. I. 210 Illustrations. 224 pages. 12mo. . . \$1.00

Vol. II. 230 Illustrations. 262 pages. 12mo. . . \$1.00

Vol. III. 390 Illustrations. 307 pages. 12mo. . . \$1.00

Vol. IV. 226 Illustrations. 276 pages. 12mo. . . \$1.00

**RICHARDSON.—The Practical Horseshoer:**

Being a Collection of Articles on Horseshoeing in all its Branches which have appeared from time to time in the columns of "The Blacksmith and Wheelwright," etc. Compiled and edited by M. T. RICHARDSON. 174 illustrations. . . \$1.00

**ROPER.—Instructions and Suggestions for Engineers and Firemen:**

By STEPHEN ROPER, Engineer. 18mo. Morocco . \$2.00

**ROPER.—The Steam Boiler: Its Care and Management:**

By STEPHEN ROPER, Engineer. 12mo., tuck, gilt edges. \$2.00

**ROPER.—The Young Engineer's Own Book:**

Containing an Explanation of the Principle and Theories on which the Steam Engine as a Prime Mover is Based. By STEPHEN ROPER, Engineer. 160 illustrations, 363 pages. 18mo., tuck . \$2.50

**ROSE.—Modern Steam-Engines:**

An Elementary Treatise upon the Steam-Engine, written in Plain language; for Use in the Workshop as well as in the Drawing Office. Giving Full Explanations of the Construction of Modern Steam-Engines; Including Diagrams showing their Actual operation. Together with Complete but Simple Explanations of the operations of Various Kinds of Valves, Valve Motions, and Link Motions, etc., thereby Enabling the Ordinary Engineer to clearly Understand the Principles Involved in their Construction and Use, and to Plot out their Movements upon the Drawing Board. By JOSHUA ROSE, M. E. Illustrated by 422 engravings. Revised. 358 pp. . . \$6.00

**ROSE.—Steam Boilers:**

A Practical Treatise on Boiler Construction and Examination, for the Use of Practical Boiler Makers, Boiler Users, and Inspectors; and embracing in plain figures all the calculations necessary in Designing or Classifying Steam Boilers. By JOSHUA ROSE, M. E. Illustrated by 73 engravings. 250 pages. 8vo. . . \$2.50

**SCHRIBER.—The Complete Carriage and Wagon Painter:**

A Concise Compendium of the Art of Painting Carriages, Wagons, and Sleighs, embracing Full Directions in all the Various Branches, including Lettering, Scrolling, Ornamenting, Striping, Varnishing, and Coloring, with numerous Recipes for Mixing Colors. 73 Illustrations. 177 pp. 12mo. . . \$1.00



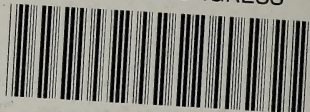








LIBRARY OF CONGRESS



0 017 100 350 7

